PREFACE.

In deference to the requests of many of his students, the author publishes this work in the form of lectures as delivered by him at the New York Dental School.

It is in no way intended that this book shall take the place of the many exhaustive text books on physiology, but the author has endeavored to present to the dental and medical student the essentials of modern physiology in a concise form. The histology and anatomy of the viscera are only considered as much as is essential for the understanding of their physiology.

The discussion of the theories regarding certain disputed questions has been purposely avoided, and only the generally adopted views have been presented. It has been thought wise to omit, as far as possible, the description of physiological apparatus and experiments, which are best understood by demonstration. Drawings have also been omitted in this book, as the lectures throughout the course are illustrated by drawings, casts, models, lantern projections, and experiments.

This book is also intended as an aid in the preparation for examination by dental- and medical-college faculties and State examining boards. The questions and exercises given at the end of each series of lectures are intended

to familiarize the candidate with the questions asked at the faculty and State Board examinations.

The author shall ever hold in grateful regard his former teacher, Prof. Bernstein, of the University of Halle, under whose guidance his studies and original investigations were made.

In the preparation of these lectures the following authors were freely consulted : Gray, Landois, Du Bois-Raymond, Bernstein, Foster, Dalton, Flint, and Kirk.

A. M.

334 East 84th street, New York City,
November, 1897.

CONTENTS OF LECTURES.

LECTURE I.

INTRODUCTION.

Ladies and Gentlemen:

Physiology is the science which treats of the normal functions of living organisms.

The human body is a complex structure of organs, each possessing different functions, whose combined activity constitutes life. The study of life, called *biology*, comprises three subjects.

1. *Morphology*, which is the study of the structure of the organs, may be either macroscopical—by means of the unaided eye—or microscopical. The former is termed *visceral anatomy*, and the latter *histology*. 2. *Physiology*, which treats of the functions of the organs. 3. The study of the growth and development of the organism, termed *embryology*.

Physiology is studied by experiment and by observation. It is essential to comprehend thoroughly the fundamental chemical and physical laws and the anatomy and histology of the organism.

Up to a century ago comparatively little was known of histology, but since then scientists have been able, due to the constant improvement in mechanical, electrical, and optical appliances, to study the subject with better and more definite results.

The first description of the structure of tissues was that of *Holland*, who stated that they were composed of fibres. Soon after that *Edwards* advanced his globular theory.

At the beginning of this century the botanist *Schleiden* detected that the tissues of plants were composed of elements which he called *cells*, and which he described as microscopical bodies consisting of a limiting membrane, within this a homogeneous substance, and in the middle of this a more solid body, the nucleus.

In 1837 *Theodore Schwann* found in animal tissues elements similar in structure to the cells of plants. Further investigations showed that all animal tissues are composed of elements which are called cells, and that to these the vital functions of the tissues must be attributed.

THE CELL.

The animal cell, as *Schwann* described it first, is a microscopical body which manifests vital properties, and which consists of a cell-wall or limiting membrane enclosing a homogeneous mass, the cell-contents or cell-body, in the centre of which is a small body, the *cell-nucleus.*

With the aid of better instruments it was observed that not all cells have a cell-wall. *Max Schultze* believed this to be merely the product of retrogressive changes in the cell-contents, and that the only essential constituents of a cell are the cell-contents, or cell-body, and the nucleus; further observations revealed the fact that some of the lower forms of animal and plant life are composed only of a homogeneous mass having no cell-wall and no cell-nucleus, and still exhibiting vital functions.

This demonstrates what is now almost universally believed, that the substance composing the cell-body is the only essential constituent of the cell, and that to it alone the vital properties of the cell must be attributed. This substance has received various names, as *blastema*, *sarcode*, *germinal matter*, *bioplasm*—as it was called by *Beale*, of this country—*protoplasm*, or first formed matter, as it was called by *Schultze.* All these designate the same thing—namely, the *living matter of a cell.*

THE PROPERTIES OF PROTOPLASM.

The protoplasm, which, as has been stated before, is the living matter of a cell, possesses certain vital properties which are common to protoplasm wherever it is found. These general properties are *motion*, *sensation*, *nutrition*, and *reproduction*.

The *amœba*, a microscopical unicellular animal organism living in the sea water, may be well used to demonstrate the vital properties of protoplasm. The amœba represents the lowest form of animal life; it consists merely of a mass of protoplasm, and has neither limiting membrane nor nucleus. If the amœba is examined under the microscope, it will be seen to possess the power to thrust outward from its main mass processes either lobular or pointed and elongated in form. These processes are termed *pseudopodia;* they adhere to other bodies and places toward which they are projected, and then draw the main portion forward, thus changing the position of the whole mass.

A similar form of locomotion is observed in cells in the human body ; it is termed *amœboid motion.*

Other forms of motion observed in animal cells are the "Brownian" and the ciliary motions. It has been observed that the particles of a cell are in constant molecular motion ; this was first described by Brown, hence the name "Brownian motion." In many parts of the body minute hair-like, protoplasmic processes are projected from the free surfaces of the cells ; these processes have a rapid vibratory motion and are called *cilia*, hence the name "ciliary motion." That protoplasm possesses the property of *sensation* is shown by experiments. External conditions, such as change of temperature, the application of certain chemicals, electricity, the alternation of darkness and light, mechanical irritation, etc., will influence the activity of the protoplasm. It has been observed that increase of temperature increases, and decrease of temperature decreases, the mobility of the amœba, and that the application

of certain chemicals produces contraction. All this tends to show that it possesses the property of sensation.

The amœba obtains its materials for *nutrition* by thrusting out from its body processes which grasp and envelop the substances the animal has selected for its food, and thus takes them up into its body, where they undergo a process of assimilation and serve purposes of nutrition, as is shown by the growth of the amœba.

The cells of the animal body take their materials for nutrition from the exudation of blood constituents into the interstices of the tissues. Protoplasm possesses the property of *reproducing its own kind.*

When an amœba has attained a certain size it shows a tendency to divide. The process begins by a constriction at the centre ; this continues until the amœba assumes an hour-glass shape, and finally separates into two distinct amœbæ, each possessing the same vital properties as the parental body.

THE STRUCTURE OF THE ANIMAL CELL.

In the higher animal organism the cells are mostly found to consist of a cell-body and a cell-nucleus.

THE CELL-BODY.

The cell-body or cell-contents is composed principally of proteid substances, the exact nature and molecular structure of which are not exactly known ; these, together with water, inorganic salts, and occasionally some fatty matter and carbohydrate material, form a generally colorless, transparent, semi-solid substance which possesses the vital properties described above. The cell-body shows generally a distinct structure consisting of a delicate fibrillar reticulum holding in its meshes a more liquid substance. Examined with a high power it will be seen that the delicate fibrillæ forming the intracellular reticulum are composed of minute granular bodies called *microsoms ;*

and it is believed that to them the more important vital processes of the cell must be attributed. These microsoms constitute particularly the substance of the cell-body, called *protoplasm*, while the substance contained in the meshes of the fibrillar reticulum is called *paraplasm*, to which more inferior physiological properties are attributed. In the cell-body there are sometimes found small cavities called *vacuoles;* they are mostly seen in the secreting cells and generally contain fluid. In other cells such substances as *pigment*, *fat*, *glycogen*, and *crystals* are seen in the cell-body.

THE CELL-NUCLEUS.

The animal cell has, with few exceptions, a nucleus. This is a minute body situated within the cell-body and generally shaped like the cell itself.

The nucleus has a complex structure similar to that of the cell-body; it consists of a *limiting membrane* enclosing a reticulum composed of delicate fibrillæ, in the meshes of which is found a liquid substance. The fibrillæ are composed of minute granular bodies called *microsoms*, which are embedded in a substance called *linin*. The limiting membrane and the microsoms are composed of an albuminoid substance belonging to the class of *nucleins*. This substance has a great affinity for coloring agents, such as methyl blue, Vesuvian brown, etc., and it is for this reason also called *chromatin*. The linin in which the microsoms are embedded, and the liquid substance contained in the meshes of the fibrillar network, possess no affinity for coloring agents and are therefore called *achromatin*. The liquid substance in the meshes of the intranuclear network is also called *paralinin* or *nucleoplasm*.

In the cell-nucleus there are sometimes seen minute bodies which also possess an affinity for coloring agents; some of these are destroyed by such agents as will destroy

chromatin substance. They are consequently only small collections of this material, and are called *false nucleoli.* Again, some of these minute bodies are not destroyed by agents which destroy chromatin matter; these are called *true nucleoli;* they are composed of an albuminoid substance called *paranuclein.*

LECTURE II.

In my last lecture I described the structure and the general physiological properties of cells, and the next question which arises is—How do the cells originate?

Up to nearly forty years ago the theory of a *spontaneous cell-generation* was held; it was supposed that particles of matter collected and spontaneously developed into a cell. It was in 1858 that *Rudolph Virchow*, Professor of Surgical Pathology at the University of Berlin, advanced his statement that all cells arise from a pre-existing cell; this statement is precisely defined by his well-known dictum, "*Omnis cellula e cellula*," which means "All cells from a cell." It is this theory which is now almost universally acknowledged.

CELL-DIVISION.

The cells of the tissues of vertebrates, including man, arise by the conjugation of the female ovum with the male cell, called the spermatozoon. The cells of the higher animal organisms multiply by *indirect division*—a process which begins with a series of changes in the cell-nucleus and is called *mitosis* or *karyokinesis*. The process may be divided into distinct phases, which are termed the *prophases, metaphases,* and *anaphases.*

In describing the process it is necessary to describe the changes which take place in the chromatic substance of the nucleus, those which take place in the achromatic substance of the same, and those which take place in the cell-body. These changes do not take place in the order stated here, but occur simultaneously in the various parts of the cell.

A. *Changes taking place in the chromatic substance of the nucleus.*—The first noticeable change in this part of the nucleus is a swelling of the fibrillar network and of the limiting membrane; then the latter disappears and the fibrillæ of the reticulum collect into a coil, called *spirem;* this coil is composed of V-shaped loops, called *chromosoms* or *chromatin loops.* The changes thus described complete the *stage of involution.*

The *second* stage consists in the arranging of the chromatin loops in the form of a *rosette.* Then the chromatin loops begin to separate at their peripheral portion and become more angular toward the centre. This results in the formation of a number of V-shaped chromatin masses, which, with their pointed portions, are directed toward the centre, and by this arrangement form the figure of a star or of an aster.

This *third* change in the chromatin portion of the nucleus is termed the *monaster* formation.

The *fourth* stage consists in the longitudinal division of the chromatin portions forming the monaster, which results in the formation of two sets of V-shaped chromatin portions; these generally separate until finally two stars or asters have formed in the cell-body. This process is known as the *diaster* formation.

Now the V-shaped branches of the two stars again unite at their peripheral ends and become more rounded at their angular portion, resulting in the formation of two rosettes. This comprises the *fifth* stage.

The next change consists in the formation of two convolutes from the chromatin loops of the two rosettes. Then appears the intranuclear network, and finally a limiting membrane forms around each of the two nuclei which have developed from the original cell-nucleus. This results from the series of changes already described, which, for a clearer understanding, may be said to consist of seven stages, as follows:

1. Involution or spirem formation.
2. Rosette formation.
3. Monaster formation.
4. Diaster formation.
5. Double-rosette formation.
6. Double-convolute formation, or dispirem.
7. Formation of the intranuclear reticula and of limiting membranes.

B. *Changes taking place in the achromatic substance.*—In the cell-body there are seen, prior to any noticeable changes in the nucleus, one or more highly refractive bodies, called *centrosoms*, which, according to some authors, arise from the protoplasm, and according to others from the achromatic substance of the nucleus. The centrosoms are surrounded by a light zone consisting of rays which radiate toward the centrosoms. This is known as the *archiplasm zone*. When the changes in the chromatic substance of the nucleus are noticeable, it will be seen that the centrosoms, with the archiplasm zones surrounding them, assume a position on either side of the nucleus. The achromatic substance in the nucleus now arranges itself into transverse rays, which become continuous with the rays of the archiplasm zone. As the chromatic portion of the nucleus begins to separate, these rays also pass transversely between the two, forming nuclei; and as the formation of these completes, the rays retreat into them and form their achromatic portion.

C. *Changes in the cell-body.*—While the changes in the cell progress, as described above, the cell-body becomes constricted near its centre, and this constriction continues until the cell separates into two portions, each containing a cell-nucleus. The centrosoms are visible until, and even after, the completion of the process described.

The *prophases* comprise the changes which take place up to the formation of the monaster; the *metaphases*, the changes which take place up to the formation of the nuclei;

and the *anaphases*, those changes which take place up to the time that the separation of the cell is completed.

Other forms of cell-multiplication which are observed in the animal cell are the direct or *amitotic* and the *heterotypic*. They are seldom observed under normal conditions.

We have already described the structure and general functions of the animal cell, and the process of the multiplication of the cells as it is observed in the tissues of the higher animal organism. The cell, after it has formed, develops, grows, performs its functions, and finally dies. The latter process also begins with certain changes in the cell-nucleus, and is called *karyolisis* or *chromatolisis*.

The cell from which the cells of the animal body arise is the ovum of the female, which, after its conjugation with the male cell, segmentates. The cell divides and subdivides by the process described above; the segmentation continues until a mulberry-shaped body, called the *blastoderm*, is formed. It is composed of a collection of simple, round, nucleated cells, called *embryonic cells*. The cells of the blastoderm now arrange themselves, by a series of changes known as *gastrulation*, into layers forming a body or mass called the *blastodermic membrane*. At first two layers are formed, called the inner and outer layers, and later on a third or middle layer appears. The *outer* layer is called the *epiblast* or *ectoderm*, the *inner* layer the *hypoblast* or *endoderm*, and the *middle* layer the *mesoblast* or *mesoderm*. Up to the time of the formation of the blastodermic membrane the cells have a uniform shape and no special characteristic properties. At the period when the inner and outer layers of the blastodermic membrane are formed its *cells begin to differentiate*. They now assume the various characteristic forms which we find in the cells of the various tissues. The cells may be classified, according to their shape, into *spherical*, *polyhedral*, *squamous*, *columnar*, *ciliated*, *branching*, and *spindle-shaped*. At the same period when these cells assume characteristic forms

they also develop *special functions* and *properties*, and, according to these, the cells of the tissues can be classified into *protecting*, *secreting*, *contractile*, *sensitive*, and *motile*.

I will give a more detailed account of the changes which take place in the ovum after its fecundation, and in the development of the structures of the animal body, when in the course of my lectures I reach the subject of embryology.

In my next lecture I shall give a description of the elementary tissues together with their physiological properties. This is essential, as these tissues enter into the construction of the numerous organs of the animal body. In order to study and understand their physiology a thorough comprehension of their histology is essential, and it is for this reason that you are required to attend a course in practical histology.

LECTURE III.

Before beginning a description of the tissues I will state that by the word tissue we understand a *collection of cells separated by an intermediate substance.*

The tissues differ, not only in the form and physiological characters of their cells, but also in the consistence of the intercellular or intermediate substance, which may be liquid, semi-solid, or solid. The tissues all arise from the layers of the blastodermic membrane. In the classification of the tissues it is hardly possible to consider them in the order of their genesis from the various layers of the blastodermic membrane, since many arise at different times, and not always from one layer, but from the different layers of the blastodermic membrane.

In my description I shall follow the following classification:

1. Epithelial tissues.
2. Connective tissues.
3. Muscular tissues.
4. Nerve tissue.
5. Fluid tissues, viz., blood, lymph, chyle.

I. THE EPITHELIAL TISSUES.

Epithelium is the first tissue developed from the layers of the blastodermic membrane. This tissue is composed of cells of various forms, which are superimposed in one or more layers upon a basement membrane, called the *membrana propria.* The cells are connected at their margins by an albuminous intercellular cementing substance, or by processes which form the so-called *intercellular bridges ;*

these leave open spaces between the cells, filled with the fluid from which the cells derive their nourishment.

Epithelium is found covering all free surfaces of the body. These are, the membranes, viz., the skin, the serous, synovial, and mucous membranes; the linings of the heart, blood vessels, lymphatics and all glands, the lining of the ventricles of the brain and of the central canal of the spinal cord.

The Functions of the Epithelial Tissues.

Epithelium has various functions, and may accordingly be classified as:

A. *Protecting* epithelium—that covering the membranes and the lining of the closed cavities.

B. *Secreting* epithelium—that covering the lining of the glands.

C. *Protecting, secreting*, and *absorbing* epithelium—that covering the lining of the alimentary canal.

D. *Sensory* epithelium—that covering the Schneiderian membrane.

E. *Motile* epithelium—the ciliated epithelium.

The epithelial tissues are found to differ in structure in the various locations in the body, and are divided into four groups—namely:

(*a*) Simple epithelium.
(*b*) Stratified epithelium.
(*c*) Transitional epithelium.
(*d*) Glandular epithelium.

The epithelium covering the lining of the closed cavities —viz., the heart, blood-vessels, the ventricles of the brain, the spinal canal, etc.—is called the *endothelium;* this belongs to the variety of simple epithelium.

(*a*) *Simple Epithelium.*

This variety is made up of a single layer of epithelial cells supported by a basement membrane. This is found covering the synovial and serous membranes, the mucous

membrane lining the greater part of the intestines and the air-passages, and the endothelial lining of the closed cavities. The cells of the simple epithelium are either flat, columnar, or cubical in shape, and are ciliated in certain parts of the body.

Flat, pavement, or *tessellated simple epithelium* is found covering the serous and synovial surfaces. The endothelial lining of the heart, blood-vessels, lymphatics, etc., also consists of a single layer of flat cells. The cells are generally many-sided and present a tiled appearance. Their sides are cemented, and each cell has generally a distinct nucleus in its centre. *Columnar simple epithelium* is found covering the mucous lining of the stomach, of the greater part of the intestinal canal, and of the ducts of many secreting glands. A variety of this epithelium, with shorter cubical, prismatic cells, is found covering the mucous lining of the smaller bronchi, of the ducts of certain secreting cells, and of portions of the uriniferous tubules. *Columnar* and *cubical simple epithelial cells* are found covering the lining of the respiratory tract, of the Fallopian tubes, and of portions of the genital tract.

(*b*) *Stratified Epithelium.*

In this variety numerous layers of epithelial cells are superimposed upon the basement membrane; of these, the basilar layer consists generally of cylindrical, the middle layer of polygonal, and the superficial layers of squamous and scaly cells. Stratified epithelium is found covering the skin and the mucous membrane of the mouth, the œsophagus, and the vagina.

(*c*) *Transitional Epithelium.*

In this variety there are also a number of layers of cells superimposed upon the basement membrane, but in such a manner that the outer layer consists of columnar, the middle layer of polyhedral, and the basilar layer of cubical cells. Transitional epithelium is found covering the mu-

cous lining of the pelvis of the kidneys, of the ureters, and of the bladder. The mucous lining of the vas deferens is also covered with transitional epithelial cells, but here the free borders of the outer cells present cilia.

(*d*) *Glandular Epithelium.*

Glandular epithelial cells are those which possess the property of secretion; their protoplasm produces materials which fill the vacuoles of the cell-body and are finally eliminated. In the human body these cells are found scattered freely between the cells of the epithelial lining of the intestinal canal; they are called *goblet-cells* and secrete a tenacious substance called *mucin.* Secreting cells are also found covering the lining of certain epithelial involutions, called *secreting glands.*

The Structure of the Secreting Glands.—A secreting gland is, as has been stated, a more or less complicated involution of epithelium.

It consists of a basement membrane supporting one or more layers of epithelial cells. A secreting gland consists of two portions—viz., a *duct* and a *secreting portion.* The duct is lined with non-secreting cubical or columnar cells. The gland is embedded in connective tissue, which supports the vessels and nerves supplying it. The secretory activity of the gland is excited by a stimulus received through secretory nerve-fibres. The secreting glands are divided, according to their structure, into:

1. *Tubular:* (*a*) simple, (*b*) compound.
2. *Acinous* or *alveolar:* (*a*) simple, (*b*) compound.

Simple tubular secreting glands are finger-like depressions, lined, in their upper part or duct, with columnar or cubical cells, and in their lower secreting portion with glandular cells. Examples of this variety are found in the mucous membrane of the stomach, small intestines, and uterus. The sudoriferous glands are also simple tubular glands, but their secreting portion is generally coiled.

Compound tubular or *branching tubular glands* are those in which the secreting portion consists of a number of tubules, all opening into one common duct. Examples of this variety are the gastric and intestinal glands.

Simple acinous or *alveolar glands* are those in which the secreting portion of a pouch like expansion is called the *alveus.* This sometimes has numerous recesses which open into it; these are called *alveoli* Glands thus constructed are called *compound acinous* or *alveolar glands;* they present a grape-like appearance, and are, for this reason, also called *racemose* glands. Examples of this variety are the salivary, the mammary glands, and the pancreas.

LECTURE IV.

II. THE CONNECTIVE TISSUES.

Having completed at my last lecture the description of the epithelial tissues, their wide distribution and important physiological functions, I will to-day take up the connective tissues. The function of these tissues is a mechanical one; they hold in place the various internal organs, connect and support the various elements of the organs, and form the skeleton, ligaments, tendons, cartilages, etc. The connective tissues are composed of an intercellular substance, which may be fibrous, homogeneous, or solid; embedded in this are the cells, also called connective-tissue corpuscles. The tissues belonging to this class are:

1. White fibrous tissue.
2. Yellow elastic tissue.
3. Areolar tissue.
4. Adipose tissue.
5. Adenoid tissue.
6. Cartilage.
7. Bone tissue.
8. Dentin, enamel, and cementum.

1. White fibrous tissue is composed of an intermediate substance formed of fibrillæ about $\frac{1}{50000}$ of an inch thick. These are arranged longitudinally in bundles and are held together by a cementing substance. Between the bundles are lodged the cells called fibroblasts; these are nucleated, quadrangular cells arranged in rows. The tendons, aponeuroses, periosteum, perichondrium, dura mater, and

the sheaths of tendons are composed of white fibrous tissue.

2. YELLOW ELASTIC TISSUE consists also of a fibrous intercellular substance, but the fibres are coarse, being about $\frac{1}{3000}$ of an inch thick and highly elastic; when cut they curl at the cut ends; seen under the microscope the fibres are colorless, but *en masse* they give to the tissues a yellowish color.

The fibres interlace and form bundles, between which flattened cells are situated. Certain ligaments—for instance, the ligamentum nuchæ—are composed of this tissue. Yellow elastic fibres are also contained in the coats of the arteries, in the lung tissue, in the vocal cords, and in areolar tissue.

3. AREOLAR TISSUE consists of fine interlacing fibres. These together form a network in the meshes of which are contained the cells; these are branched and cemented by their processes. This tissue is very widely distributed in the body. The sheaths of muscles, nerves, vessels, glands, and the basement membrane of the membranes are all composed of areolar tissue. The tissue sustaining the elements of the internal organs is also areolar.

4. ADIPOSE TISSUE consists of a network of areolar tissue holding in its meshes clusters of cells of about $\frac{1}{500}$ of an inch in diameter; these cells contain liquid fatty matter. The tissue also supports blood-vessels and nerves. Adipose or fat tissue is present to a greater or less degree in almost all parts of the body.

The purposes and functions of adipose tissue are (*a*) to serve as a storehouse for combustible matter which may be used by the tissues when required; (*b*) to act as a packing material, thus preventing pressure upon delicate structures; (*c*) to prevent an undue escape of heat from the surface of the body, since the adipose tissue contained beneath the skin is a poor conductor of heat.

5. ADENOID TISSUE, also called *retiform* or *lymphoid* tis-

sue, is that which makes up the stroma of the spleen, tonsils, lymphatic glands, etc. It consists of a fibrillar network holding in its meshes the so-called lymphoid corpuscles; these are spherical cells with large nuclei.

6. CARTILAGE. This tissue consists of a semi-solid, dense intercellular substance called the matrix. In it are embedded the cartilage cells, or *chondroblasts*, which have various forms and often contain glycogen. Cartilage, when boiled, yields a gelatinous substance called *chondrin*. All cartilage, except that covering the articular surface of bone, is covered by a dense fibrous membrane, called the *perichondrium*, which closely adheres to the cartilage and serves for its nutrition. The function of cartilage is to give strength and elasticity; it is therefore found in the body wherever a strong, elastic, yielding substance is required—for instance, in the larynx and trachea, where it serves to keep them in shape, or between articular surfaces of bones, where it prevents jarring of the body. In the human body we find three varieties of cartilage, namely: (*a*) *hyaline* cartilage, (*b*) *yellow elastic* cartilage, (*c*) *white fibrous* cartilage.

(*a*) *Hyaline cartilage* consists of a matrix composed of a homogeneous, translucent material, and containing small cavities called *lacunæ*. In these are embedded from four to eight irregular-shaped cells, each of which has a nucleus and a nucleolus. The lacunæ are lined with a delicate membrane, and are connected with each other by minute channels which transmit nutritive material. The cartilages of the bronchi, trachea, nose, some of those of the larynx, and the articular cartilages of the joints, are of this variety. (*b*) *Yellow elastic cartilage* consists of a matrix of hyaline material and of yellow elastic fibres; the cells are more round than those of the hyaline variety. The epiglottis, the cornicula laryngis, the cartilaginous portion of the Eustachian tube, and the cartilages of the auricle of the external ear are of this variety.

(*c*) *White fibro-cartilage.* In this variety the matrix consists, as the name implies, of a fibrous material. The cells are flattened and sometimes branching. This cartilage is very abundant in the human body. The intra-articular cartilages between certain joints; the circumferential cartilages attached to the margin of certain joint-cavities, like the glenoid, the acetabulum, etc.; the connecting cartilages between the vertebræ; and, lastly, the so-called sesamoid cartilages contained in the sheaths of certain tendons—are all composed of white fibro-cartilage.

7. BONE. This tissue is composed of earthy and animal matter. The former consists chiefly of calcium phosphate and constitutes 67 per cent of the bone substance, while 33 per cent is animal matter. A bone consists of a compact external layer and a spongy or cancellous internal portion.

The structure of bone tissue. The compact and cancellous portions of bone have both the same structure. Bone tissue, when examined under the microscope, is seen to consist of numerous openings, around which are arranged concentric rings of bone tissue. In this are seen minute cavities, which are connected with each other and with the central opening by delicate channels. Such a circular arrangement of bone tissue is called the *Haversian system,* after *Clopton Havers,* who first described it. The central opening in each ring is the opening of a *Haversian canal.* The bony ring around this is called the *lamella,* the minute cavities are termed *lacunæ,* and the channels connecting these with each other and with the central opening are the *canaliculi.*

The Haversian canals are channels running parallel with the long axis of the bone. In their course they branch off, communicate with each other, and issue either at the surface of the bone, or at the medullary canal by the minute openings through which blood-vessels and lymphatics enter the bone.

The lacunæ are small, oblong cavities and contain the bone-cells.

The bone-corpuscles are flattened, nucleated cells with branches which project into the canaliculi. They are surrounded by fluid nutrient matter, which is conveyed thither through the canaliculi. The bone-cells, or *osteoblasts*, are the bone-forming cells. The space between the concentric rings of bone-tissue just described is also composed of bone-tissue, and is called the *interstitial lamella.* It contains lacunæ and canaliculi, but not in a characteristic arrangement as in the Haversian system. The long bones present an external ring of compact bone-tissue, called the *circumferential lamella*, the structure of which is the same as that of the interstitial lamella.

Bone-tissue receives its nutrition through the periosteum and through the marrow. The *periosteum* is a dense, highly vascular, fibrous membrane which closely adheres to the outer surface of the bone, and from which blood-vessels pass into the bone-substance.

The *marrow* of bone is of two kinds: (*a*) Yellow marrow is that which is contained in the central canal of the long bones; it is composed of areolar tissue which supports fat-cells and blood-vessels ; from the latter there are branches which enter the bone-substance. (*c*) Red marrow is that contained in the spongy bone-tissue; it is very vascular, and chiefly composed of marrow-cells which resemble lymphoid corpuscles ; these cells are sometimes reddish, and are believed to be in a transitional stage from marrow-cells to red blood-corpuscles. Bone-tissue is developed from the osteoblasts.

8. Dentin, Enamel, and Cementum. These are the tissues which enter into the construction of the teeth. A tooth consists of a *crown*, a *neck*, and one or more *roots.* The last mentioned are those portions of the tooth which are contained in the alveoli of the alveolar process of the jawbone. The interior of a tooth is a cavity, which gene-

rally takes the form of the tooth. This contains the *pulp* and is called the *pulp-chamber.* The apex of each root presents an opening, the *foramen dentium,* which transmits the structures forming the pulp. The pulp consists of blood-vessels and nerve-filaments, held together by areolar tissue. The pulp is covered by a single layer of elongated cells, the *odontoblasts;* these are connected by processes with the pulp, and also project elongated processes into the dentinal canals of the dentin.

The *dentin* is one of the hardest tissues in the human body. It consists of a matrix of inorganic material, pierced by numerous slightly curved S-shaped channels, called the *dentinal canals,* which radiate from the pulp-chamber toward the periphery of the dentin, where they open into small spaces called the *interglobular spaces.* The dentinal canals are lined with a delicate membrane, called the *dentinal sheath.* These canals contain the *dentinal fibres,* which are the prolonged processes of the odontoblasts; they terminate at the periphery of the dentin, and are here connected with the poles of the branching cells contained in the interglobular spaces. The dentin forms the main mass of the body of the tooth; it has the shape of the tooth and surrounds the pulp. The dentin of the crown is covered by the enamel, that of the root or roots by the cementum.

The *enamel* is the hardest tissue in the human body. It consists of prisms composed of inorganic material; these are set at right angles upon the surface of the dentin, forming the crown of the tooth. Enamel contains only from 3 to 5 per cent of organic material. In early life the enamel is covered by an exceedingly delicate membrane, called the *cuticula.*

The *cementum,* or *crusta petrosa,* is bony tissue which, in a thin layer, covers the dentin of the roots of the teeth. The bone-cells contained in its lacunæ are connected by this elongated process with the branched cells contained in the interglobular spaces. Externally the cementum is

covered by a dense, delicate vascular membrane, which closely adheres to the cementum, and which to some extent supplies nutritive material to the tooth; it is called the *pericementum* and is continuous with the periosteum lining the alveoli.

In the lectures on dental histology you will listen to a more detailed description of the structure of the teeth. On their functions and on their development I will dwell in future lectures.

LECTURE V.

In my last lecture I finished the description of the elementary tissues. To-day I shall begin that of the higher specialized tissues—viz., those of the muscles and nerves. At present I will consider the histology and physiology of these tissues only so far as it is essential for a proper understanding of those physiological functions of which I will speak in the next series of lectures.

In my lectures on animal motion and on the physiology of the nervous system I will consider these tissues more in detail, paying especial attention to their physiology.

III. THE MUSCULAR TISSUES.

In the human body we find three varieties of this tissue —the plain or non-striated, the striated, and the cardiac muscle.

Plain or Non-striated Muscle Tissue.—This variety is found in the coats of the blood-vessels, lymphatics, ducts of glands, in the walls of the gall-bladder, urinary bladder, ureters, stomach, intestines, uterus, trachea, bronchi, lower half of the œsophagus, also in the eye and in the skin.

The Structure of Plain or Non-striated Muscle Tissue.—The histological elements of this tissue are the *contractile fibre-cells.* These are elongated, flat, spindle-shaped, nucleated cells which are from $\frac{1}{600}$ to $\frac{1}{300}$ and even to $\frac{1}{10}$ of an inch long, and $\frac{1}{4500}$ to $\frac{1}{3500}$ of an inch wide at their widest part. These cells have an elastic limiting membrane. The cell-body consists of longitudinally arranged fibrillæ, which are the real contractile elements of the cell. The elongated nucleus has a limiting membrane and a

stroma of longitudinally arranged fibrillæ, which, at the poles of the nucleus, anastomose with the fibrillæ of the cell-body. These cells are held together by a cementing material and by connective tissue.

Striated Muscle Tissue.—This variety forms the muscles of the skeleton. The structure of this tissue is more complicated than that of the former variety. Striated muscle tissue consists of fibres which are from one-half to two inches long and $\frac{1}{600}$ to $\frac{1}{300}$ of an inch in diameter. These fibres are surrounded by a delicate sheath, the *sarcolemma.* Examined under the microscope the fibres present alternating dark and light lines; these run transversely, being $\frac{1}{1200}$ of an inch in width. The dark lines present minute longitudinal striæ, which divide each into a row of quadrangular particles, called *sarcous elements.* The light lines are divided into halves by a transverse dark streak; this is formed by a delicate membrane, called *Krause's membrane,* which passes from one side of the sarcolemma to the other. This membrane divides the inside of the muscular fibre into compartments, called *discs of Bowman.* Each compartment consists of a row of sarcous elements forming a dark line, and a translucent cementing material which holds the sarcous elements together ; this substance forms the delicate longitudinal striæ in the dark lines, and the portions of the light lines which are between the dark line and Krause's membranes. A continuous connective tissue holds the individual fibres in bundles. A number of these together form fasciculi ; a group of fasciculi forms a muscle, which is surrounded by a sheath. The connective tissue holding together the fibres in bundles is called *endomysium;* that holding the bundles together, the *internal perimysium;* and that holding the fasciculi together to form and surround a muscle is called the *external perimysium.*

The Cardiac Muscle Tissue.—This variety is, as the name implies, the tissue which forms the heart muscle. Its structure resembles that of the striated variety, in that it

is also made up of fibres which have a striated appearance. The fibres are only about one-third the size of those of the voluntary muscles. They have no sarcolemma, and their transverse and longitudinal striæ are less distinct. The fibres consist of oblong, nucleated prisms, and branch off and anastomose with each other; the connective tissue holding them together is less abundant than in the former variety.

The physiological property of muscle tissue is its contractility. This is an inherent property, as shown by the fact that it will also exert this activity, under certain conditions, when all nervous connections with the muscles are severed. The activity of muscle tissue is generally excited by stimuli received through nerves. The activity of the skeleton muscles is under the control of the will, and these muscles are for that reason called *voluntary muscles;* whereas the activity of the non-striated and the cardiac muscle tissue is not under the control of the will, and they are therefore called *involuntary muscles.*

IV. THE NERVE-TISSUE.

The histological and physiological elements which enter into the structure of the nerve-tissue are: (*a*) nerve-cells, (*b*) nerve-fibres, and (*c*) connective tissue. The peripheral termini, which also are portions of the nervous system, possessing a special structure, will be described in my lectures on the physiology of the nervous system.

(*a*) *Structure and Functions of the Nerve-Cells.*—Nerve-cells, nerve-vesicles, or ganglionic cells vary in size from $\frac{1}{500}$ to $\frac{1}{10}$ of a millimetre in diameter. They are either angular, oval, or stellate in form, and generally have one or more protoplasmic processes, called *poles;* accordingly nerve-cells are said to be unipolar, bipolar, tripolar, or multipolar. These poles either terminate in a point, or anastomose with the poles of other nerve-cells, or continue as the axis-cylinder of a nerve-fibre. Nerve-cells have no distinct cell-wall, but a clear round or oval nucleus with

an intranuclear network and generally a nucleolus. The cell-body is composed of a reddish granular protoplasm. Nerve-cells are the chief structure of the nerve-centres.

The physiological functions of the nerve cells may be enumerated under the following heads: *Conduction*, *reflection*, *transference*, *automaticity*, *augmentation*, and *inhibition*. *Conduction* is the property possessed by certain nerve-cells enabling them to conduct impressions to other nerve-cells or centres. *Reflection* is the property by which certain nerve-cells transmit to the periphery impulses received through nerves coming from the periphery. *Transference* is the property by which certain nerve-cells interposed in the course of nerves or nerve-fibres transfer impulses from one nerve fibre to another. *Automaticity* is the property enabling certain nerve-cells to originate impulses without external stimuli. *Augmentation* is the property of augmenting, altering, or influencing the kind and quality of certain nerve impulses. *Inhibition* is the property which certain nerve-cells possess enabling them to inhibit the activity of others.

In my lectures on the physiology of the nervous system I will more fully explain and illustrate these functions of the nerve-cells.

(*b*) *Structure and Functions of the Nerve-Fibres.*—Nerve-fibres are the chief structures entering into the formation of the nerves. Nerve-fibres are either medullated or non-medullated. A medullated nerve-fibre consists of: (*a*) The *axis-cylinder*. This is the essential portion of all nerve-fibres; it is of a reddish-gray color, consists of delicate fibrillæ, and is, as the name implies, the central portion of the nerve-fibre. The axis-cylinder passes uninterruptedly from origin to end; its physiological function is to convey impulses or impressions either to or from the centre. (*b*) The *medullary sheath*, also called the *white substance of Schwann*, or *myeline sheath*, is a semi-solid, whitish, fatty substance surrounding the axis-cylinder; its thickness varies. The function of the medullary sheath is to serve

as an isolating material. Non-medullated nerve-fibres are not surrounded by this medullary sheath. (*c*) The *connective tissue.* Tissue of this variety enters into the structure of the nerve-tissue; it serves to hold its various structures together.

Neurilemma is a delicate fibrous membrane which surrounds certain nerve-fibres. In this delicate tubular sheath are seen at intervals large, oval nuclei surrounded by protoplasmic masses; these are called nerve-corpuscles, and they are believed to be remnants of an embryonic life. At intervals the neurilemma of many medullated nerve-fibres presents constrictions by which the continuance of the medullary sheath is interrupted, because of which the nerve-fibres present a nodulated appearance The nodules are called *nodes of Ranvier.* Not all nerve-fibres have a neurilemma. *Endoneurium* is the connective tissue which holds in a bundle a number of individual nerve-fibres. *Perineurium* is the connective tissue which holds together the bundles forming a nerve-trunk. The *epineurium* is the connective tissue which forms the sheath of a nerve-trunk. The *neuroglia* is a special form of connective tissue which supports and holds together the elements of the brain and spinal cord. It consists of a homogeneous, fatty, whitish substance which contains delicate fibrillæ holding in their meshes nucleated cells.

This finishes the description of the structures forming the nervous system, and I repeat that it is merely introductory to your practical work in histology and to your studies of the physiology of the nervous system.

With this lecture I also finish the description of the tissues, as far as I intend to treat of them in this series of lectures, which are really only preliminary and introductory to the subject of physiology. The tissues mentioned in the classification under No. 5—namely, the fluid tissues—are the *blood*, the *lymph*, and the *chyle*. These are fluids consisting of cells and a fluid intermediate substance, hence the name fluid tissues. The lymph and the chyle I will

describe when speaking of the subjects of digestion and absorption. The subject of my next lecture will be the blood.

QUESTIONS AND EXERCISES.

SUBJECT.—*Terminology. Definitions. The cell; the cell theory; cell multiplication. The tissues; their structure, function, and distribution.*

Lectures I.–V. inclusive.

1. What is physiology?
2. What is biology?
3. What is morphology?
4. What is histology?
5. What is embryology?
6. What is a cell?
7. What is the first description of the animal cell?
8. What is the essential part of a cell?
9. What is protoplasm?
10. What is a cell-wall?
11. What is a cell-nucleus?
12. Describe the minute structure of the cell-body.
13. Describe the minute structure of the cell-nucleus.
14. What is a chromatic and what is an achromatic substance?
15. What are the chemical constituents of protoplasm?
16. What are the properties of protoplasm?
17. How do cells originate?
18. How do the cells of the higher animal organism generally multiply?
19. Describe the process of indirect cell division:
    (*a*) The changes taking place in the chromatic substance of the nucleus.
    (*b*) The changes taking place in the achromatic substance.
    (*c*) Those of the cell-body.

20. Describe the various forms of cells found in the tissues of the human body.

21. Describe the special functions of the various cells of the tissues.

22. What is a tissue?

23. Name the varieties of epithelial tissues.

24. Describe the structure, the functions, and the distribution of (*a*) simple, (*b*) transitional, and (*c*) stratified epithelium.

25. Describe the various forms of secreting glands, and name examples of each.

26. Name the connective tissues.

27. Describe the structure of white fibrous tissue and its distribution.

28. Describe the structure of yellow elastic tissue and its distribution.

29. Describe the structure and distribution of (*a*) areolar, (*b*) adenoid, and (*c*) adipose tissue.

30. Describe the varieties of cartilage, their structure and distribution.

31. Describe the structure of bone-tissue.

32. Describe the structures which enter into the construction of a tooth.

33. What are odontoblast, dentinal fibres, dentinal sheath?

34. What is the physiological function of muscle-tissue?

35. Name the varieties of muscle-tissue.

36. Describe the structure of non-striated muscle.

37. Describe a striated muscular fibre.

38. Describe the structure of cardiac muscle.

39. Define external perimysium, internal perimysium, endomysium, sarcolemma.

40. Name the structural elements which enter into the construction of the organs of the nervous system.

41. Describe the structure of a nerve-cell.

42. Explain the physiological functions of a nerve-cell.

43. Describe the structure of a medullated nerve-fibre.

44. Explain the difference between a medullated and non-medullated nerve-fibre.

45. Explain the physiological functions of nerve-fibres.

46. Define neurilemma, endoneurium, perineurium, epineurium.

47. What is neuroglia? Describe its structure.

48. What are the fluid tissues?

49. What variety of membrane, serous or mucous, lines the inside of each of the following: abdominal cavity, alimentary canal, thoracic cavity, nasal passages, eyelids?

50. What is the function of adipose tissue?

51. Describe the structure of muscle.

52. Describe the structure of a tooth.

53. Describe the development of the nuclei of cells.

54. Define the function of the mucous membrane of the respiratory tract.

55. To what class of tissues do teeth belong?

56. Define tissue.

57. Describe a nerve-fibre.

58. What is the function of the serous and the synovial membranes?

59. Give the functions and localities of each of the different varieties of epithelia.

60. Describe an amœba.

61. What is the function of the Schneiderian membrane?

62. How are cells reproduced?

63. Describe ciliary motion.

64. Describe protoplasmic movement.

65. Describe the decay and death of cells.

66. How are cells connected?

67. Name the physical properties of protoplasm.

68. Draw a cell, designating three parts of it.

LECTURE VI.

THE PHYSIOLOGY OF THE BLOOD.

All living organisms receive their nutrition from a juice which permeates all parts. In the lower forms of animal life this juice is either colorless or somewhat yellow. In higher forms it is red and is called the blood; it circulates in a closed system of vessels which are distributed to all parts of the body.

Human blood is an opaque fluid. For a proper understanding of its physiology it is necessary to describe and explain its physical properties, such as its color, specific gravity, reaction, odor, taste, etc., before describing its morphological constituents.

The *color* of human blood varies from scarlet or dark-red to purple. The color of the blood is due to a coloring material contained in the red blood-corpuscles; this is called *hæmoglobin*. It forms with oxygen a bright-red compound; the combination is an unstable one, and the oxygen is easily given off again when pressure is removed. The hæmoglobin thus reduced has a dark-red color. This explains the difference between the color of the blood in the arteries and capillaries and that in the veins.

The *specific gravity* of human blood varies from 1045 to 1055; it is generally higher in man than in woman. The specific gravity of blood is dependent upon the quantity of hæmoglobin in the blood, and also upon the comparative quantity of water.

Fasting, or any condition in which large quantities of liquid are taken, decreases the specific gravity of the blood

whereas any condition in which large quantities of water are given off through the skin, intestines, or kidneys increases it.

Pathological conditions which influence the quantity of red blood-corpuscles or of their hæmoglobin also influence the specific gravity. It is for this reason that in anæmia, chlorosis, nephritis, and in marasmatic conditions the specific gravity of the blood is lowered.

The *reaction* of human blood is slightly alkaline, due to the presence of alkaline salts in the blood. The alkalinity of the blood is generally greater in men than in women and children. When blood is taken from the circulatory system it soon loses its alkalinity; this is believed to be due to an acid which forms during the decomposition of the hæmoglobin. Muscular exercise, the taking of acids, and fasting decrease, and the reverse conditions increase, the alkalinity of the blood. Many pathological conditions also influence the alkalinity, which is increased in chlorosis and in diseases of which excessive vomiting is a symptom; a marked decrease of the alkalinity of the blood is observed in anæmia, uræmia, rheumatism, gout, cholera, and in febrile conditions. The same result takes place when poisonous substances are taken which destroy the red blood-corpuscles.

It is of great importance for the clinician to be able to determine the relative alkalinity of the blood. The process used for this purpose is as follows: A weak solution of tartaric acid (7.5 to 1000.0) is prepared; a sufficient amount of this is added to a given volume of blood to render it neutral, as shown by the use of litmus paper. A test with this solution will demonstrate that 1 cubic centimetre neutralizes 0.0031 of sodium. Knowing this, and knowing the quantity of the stated solution which is required to neutralize a given volume of blood, it is but a simple matter to calculate from this the relative alkalinity of that volume of blood: 100 cubic centimetres of normal human

blood have an alkalinity representing 0.260 to 0.300 gramme of sodium.

The *odor* of human blood is a characteristic one, due to the presence of certain volatile fatty acids.

The *taste* of human blood is saline and is caused by the presence of salts, especially of sodium chloride.

To the *touch* blood is warm and sticky.

The *morphological elements* of the blood are :

1. The *cells*—viz., (*a*) the red blood-corpuscles, (*b*) the white blood-corpuscles, (*c*) the blood-plates or blood-plaques (of late considerable importance has been attributed to these).

2. The *plasma*, or *liquor sanguinis*, which is the intercellular substance.

The blood, therefore, like the lymph and chyle, is a fluid tissue consisting of cells and an intercellular substance. In describing its morphological elements I will first take up the corpuscles and then the plasma, and describe the composition, physical, chemical, and physiological properties of each, and then dwell on the physiology of the blood in general.

I. THE BLOOD-CORPUSCLES.

A. *The Red Blood-Corpuscles or Erythrocytes.*—These are cellular elements which float in great numbers in the blood. In the human blood they were first observed by Van Leeuwenhoeck in 1673.

A human red blood-corpuscle is a circular disc with a central depression in each flat surface, so that, seen from the side, it is biscuit- or dumbbell-shaped. Erythrocytes have no cell-wall and no nucleus ; their body is composed of a homogeneous gelatinous protoplasm and is very elastic. A human red blood-corpuscle is about $\frac{1}{125}$ of a millimetre in diameter, $\frac{1}{375}$ of a millimetre thick at the edges, and $\frac{1}{500}$ of a millimetre thick at the thinnest portions. Human red blood-corpuscles when taken from fresh blood can be recognized as such by their form and size.

All mammalia have disc-like erythrocytes, with the exception of the camel, the llama, and other members of that family, which have elliptical red blood-corpuscles. The birds, reptiles, amphibiæ, and fishes have oval or elliptical erythrocytes which contain a large, protruding nucleus.

In all cases where the red blood-corpuscles of mammalia are circular and disc like they are smaller than those found in human blood, with the exception of those of the elephant, which are larger, and those of the ape, which are but slightly smaller than those of human blood.

When seen under the microscope red blood-corpuscles are straw-colored. If blood is examined microscopically it can be seen that the red blood-corpuscles have a tendency to cling together with their flat surfaces, thus forming pillars resembling rolls of coins. This phenomenon is not fully explained, but it is probably due to changes in the corpuscles. In circulating blood and in that stagnant in the blood-vessels this tendency has not been observed.

When red blood-corpuscles are kept for a time changes in their form can soon be observed: they either diminish in size and assume a mulberry-shape, caused by the giving off of water, or swell and become rounded on the addition of water which is taken up by the corpuscles. Liquids used to preserve red blood-corpuscles are: a physiological solution (0.6 per cent) of sodium chloride, a 1 per cent solution of egg-albumen, and Pacini's fluid. The latter is composed of hydrarg. bichlor., 2 parts; natr. chlorat., 4 parts; glycerin, 26 parts; aq. destillat., 226 parts. For use this solution is diluted with two parts of distilled water.

Red blood-corpuscles are composed of two substances, viz., the *hæmoglobin* and the *stroma.*

The chemical composition of red blood-corpuscles is as follows: water, 681 in 1,000 parts; solids, 319 parts (inorganic solids, 7; organic solids, 312). The inorganic constituents are the salts of potassium, sodium, phosphorus,

and magnesium. The organic constituents are hæmoglobin, albumin, lecithin, cholesterin.

The *hæmoglobin* is the coloring matter of the red blood-corpuscles. It is a nitrogenized, organic, crystallizable substance, composed of oxygen, hydrogen, nitrogen, carbon, sulphur, and iron. HO is the symbol used for the word hæmoglobin. HO can be obtained from the blood by various processes in the form of rhombic plates and prisms. It is soluble in water, but insoluble in alcohol, chloroform, ether, and fats.

The quantity of HO in the total quantity of blood is in men 13.77 per cent; in women, 12.59 per cent; during pregnancy only 9 to 12 per cent. It is highest in the new-born, diminishes after the tenth week, reaches the minimum between the first and fifth years, then gradually increases, and after the forty-fifth year decreases again.

In certain pathological conditions the quantity of HO decreases—for instance, in anæmia, chlorosis, in all febrile and chronic diseases, and in marasmatic conditions. It is, therefore, of great importance to the clinician to determine the quantity of HO in the blood. This can be determined with the use of the hæmameter and also with the spectroscope. Another method is to determine the quantity of iron in the blood, from which the quantity of HO can be calculated. HO contains 0.42 per cent of iron by weight.

HO consists of two substances, viz., the *hæmatin* and an albuminous, colorless substance belonging to the class of globulins.

Hæmatin is an amorphous, dark-blue or brownish substance containing iron; it is not soluble in water, alcohol, or ether. When dried HO is treated with glacial acetic acid and sodium chloride, and heat is applied, minute crystals are produced which are dark-blue or brown and have the form of rhombic plates or prisms. These are hæmatin crystals, composed of one part of hæmatin to two of HCl. It can be produced from the smallest parti-

cles of dried blood-stains, and is for this reason of great importance in forensic medicine, especially so because the form of the crystals is characteristic.

HO, under certain conditions, enters into chemical combination with gases in the body. We find in the body the following HO combinations: oxyhæmoglobin, methæmoglobin, and CO hæmoglobin; a fourth substance, also a result of chemical changes of HO, is the hæmatoidin, which is found in the body under certain conditions. Oxyhæmoglobin (OHO) forms readily when HO comes in contact with O or with air. OHO is less soluble than HO and differs from it in the bands of the spectrum. OHO is found in the erythrocytes of the blood in the arteries and capillaries. It is a very loose chemical compound, and readily gives off its O to the tissues of the body; it is then called *reduced HO.*

Methœmoglobin—MetHO—is a more stable compound of HO with O; it is spontaneously formed in bloody urine, cysts with bloody contents, and in old blood extravasations. It differs from OHO in the arrangement of the bands in the spectrum.

Carbonic oxide—HO(CO-HO)—is a chemical compound which is readily formed when CO comes in contact with OHO or HO. It is cherry-red, and when heated with a ten per cent sodium hydrate solution gives a bright-red color. CO-HO is formed in the body when CO is inhaled. One volume of CO replaces one volume of O in HO.

CO poisoning occurs when sufficient CO is inhaled to decrease the quantity of O in the blood to such an extent as to interfere with the vital functions of the tissues depending upon a proper oxidation. Death occurs before all O is replaced by CO.

The symptoms of CO poisoning are: headache, restlessness, increased cardiac action, rapid circulation, convulsions; later on, loss of consciousness, difficult respiration, rapid small pulse; and, finally, loss of sensation, cessa-

tion of cardiac and respiratory action, death. The blood-vessels are first contracted, then dilated, the organs being congested and filled with cherry-red blood. One thousand cubic centimetres of CO breathed at one time produce death. Patients suffering from CO poisoning should be removed into the fresh air and artificial respiration and stimulation resorted to; in advanced cases transfusion of blood is required. CO–HO is also formed in the blood when minor quantities of CO have been inhaled with the air, but through the respiratory process the CO is gradually replaced by oxygen.

Hæmatoidin is another substance which is formed in the body by a chemical change of HO. It is found in old extravasations of blood in the brain. It is always found in the Graafian follicle after its rupture during the menstrual period. Hæmatoidin is formed from HO when the latter gives off iron and takes up water; it is bright red and crystallizes in klinorhombic stars, prisms, and plates.

The number of red blood-corpuscles has been estimated to be about four to five millions in one cubic millimetre of blood; generally it is over five millions in men and about four millions in women. It is increased after the taking of solid food and when large quantities of water are given off through the skin, kidneys, or intestines. It is decreased after the taking of large quantities of fluid. In women it is generally decreased during pregnancy. Variations in the blood-pressure, and many pathological conditions, such as hydræmia, anæmia, etc., influence the absolute and relative quantity of erythrocytes in the blood. It is, therefore, of no little importance that the clinician be able to determine such variations. The apparatus generally used for that purpose is the Abbe-Zeiss counting apparatus. This consists of a mixing pipette and a counting chamber. The mixing pipette consists of a capillary glass tube, at the upper portion of which is a bulbous expansion, and within this a glass pearl serving to thoroughly mix the fluids

drawn up into it. The lower end of the tube is pointed; to the end above the bulbous expansion a rubber tube may be attached through which the fluids are drawn up into the tube bulb. The pipette has engraved on it the figures $\frac{1}{2}$, 1, and 100. The bulbous expansion is between the marks 1 and 100; it holds one hundred times more than the capillary tube from the point to the mark 1, and two hundred times more than the capillary tube from the point to the mark $\frac{1}{2}$.

The counting chamber consists of a glass cell $\frac{1}{10}$ of a millimetre deep; this is fastened upon an object glass; the floor of the cell is divided into squares of $\frac{1}{400}$ of a quadratmillimetre each. The cubic contents of the space above each of these little squares of the counting chamber is therefore $\frac{1}{4000}$ of a cubic millimetre.

The method of counting the red blood-corpuscles with the use of this apparatus is as follows: First, the blood is diluted with 200 or 100 volumes of a physiological (0.6 per cent) solution of sodium chloride in water; a 3 per cent solution of NaCl may also be used. This is done by drawing up the blood into the pipette to the mark $\frac{1}{2}$ or 1, and then the salt solution is drawn up to the mark 100; by thoroughly shaking the pipette the blood is mixed well with the salt solution. After blowing out the liquid contained in the capillary portion of the tube, a drop of the mixture in the bulbous portion is carefully dropped into the counting chamber, a cover-glass is applied, and, with the use of the microscope, the average number of red blood-corpuscles contained in one square of the counting chamber—namely, in $\frac{1}{4000}$ cubic millimetre—is obtained; this again is multiplied by 4,000, and the resulting number is again multiplied by 200 if the dilution of blood is $\frac{1}{2}$: 100, and by 100 if the dilution is 1 : 100; the result is the number of red blood-corpuscles contained in one cubic millimetre of undiluted blood.

The origin of the erythrocytes in embryonic life is

believed to be from large protoplasmic spheres in which, by an endogenetic process, red blood-corpuscles are formed; this has been observed to take place in the chicken in the first days of embryonic life. Later on such protoplasmic spheres in which red corpuscles have formed are seen in the liver and spleen, and in the lymphatic glands surrounding these. The corpuscles formed within these cells contain HO and are nucleated; later on the nucleus disappears, the protoplasmic surrounding shrinks, and finally a typical erythrocyte appears. In post-embryonic life the erythrocytes are found within the large so-called *vaso-formative* cells from which the capillaries are formed. In later life the red corpuscles are formed in the red marrow of the bones; in this, nucleated spherical cells appear which contain HO. They are believed to be leucocytes in a transitional stage in the formation of red blood-corpuscles, and they are therefore called *erythroblasts*.

The duration of the life of the red blood-corpuscles in our body is short. After a period of four to five weeks they undergo a process of destruction believed to take place in the liver, because the blood in the hepatic vein shows a marked decrease in the number of red corpuscles as compared with the blood in the portal vein.

The coloring matter and other ingredients of the bile are formed as the result of the destructive process of the red blood-corpuscles in the liver.

The physiological function of the erythrocytes is the taking of oxygen from the inspired air and the carrying of it to the tissues, where it is given off to serve as an oxidizing agent.

LECTURE VII.

THE PHYSIOLOGY OF THE BLOOD (*continued*).

B. THE *white* or *colorless corpuscles* were first observed in the human blood by Hewson in 1776. They are spherical, having a granular protoplasm, generally several nuclei, but no cell-wall. The granules of the protoplasm are more distinct in some than in others, and also differ (according to Ehrlich) in their affinity for staining agents which vary in their reaction; thus he found that the protoplasm granules of certain corpuscles have a peculiar affinity for acid, others for basic, and again others for neutral staining agents, and he called the granules respectively *eosinophile, basophile,* and *neutrophile* granules. Observations are of no little importance to the clinician, as in certain pathological conditions the one or the other kind of these granules is increased or prevalent. For instance, in leukæmia the blood contains an increased number of white corpuscles, in which are found eosinophile granules; in inflammatory conditions colorless blood-corpuscles having neutrophile granules, and in chronic inflammatory conditions colorless corpuscles having basophile granules, are found in the tissues where they have migrated from the blood. The nuclei of the colorless corpuscles are not clearly visible, but become so upon the addition of acetic acid.

The size of the colorless corpuscles varies. In human blood three sizes are found, varying in diameter from $\frac{1}{250}$ to $\frac{1}{75}$ of a millimetre; the smallest are smaller than the erythrocytes and have a fine granular protoplasm and generally one nucleus; others are of the same size as the

erythrocytes, and again others are considerably larger; these generally contain very refractive protoplasmic nuclei.

The *specific gravity* of colorless blood-corpuscles is but slightly higher than that of the plasma (1027).

The *chemical composition* of colorless blood-corpuscles is as follows: albumin, alkaline-albumin, nucleo-albumin, nuclein, glycogen, cholesterin, lecithin, fat, and the salts of sodium, potassium, and phosphorus.

The *number* of colorless corpuscles in the human blood is about 1 to 3 to 500 red corpuscles. This proportion varies greatly in different locations; venous blood generally has more colorless corpuscles than arterial blood.

In the splenic vein the proportion is 1 white to 60 red corpuscles; in the splenic artery it is 1 to 2,260; in the portal vein it is 1 to 740, and in the hepatic vein 1 to 170.

The number of colorless corpuscles is generally greater in women than in men, and greater in children than in grown persons. The number is increased during the process of digestion, during menstruation, after a loss of blood, after childbirth, when tonic drugs, such as chinin, nuclein, etc., are taken. The number is very much increased in a pathological condition called leukæmia, in which the proportion is sometimes found to be 1 white to 2 red blood-corpuscles.

The number is decreased during fasting and when the body is in a poorly nourished condition.

The counting of colorless corpuscles is done by a method similar to that employed for the counting of erythrocytes, only that a one-third per cent solution of acetic acid is used to dilute the blood.

The origin of the white or colorless corpuscles is evidently in the spleen, as is shown by the enormous quantity of them in the splenic vein as compared with their number in the blood of the splenic artery. To a large extent the white blood-corpuscles originate in the lymphatic glands and the marrow of the bones.

White blood-corpuscles multiply partly by mitosis, partly by amitosis.

Cells similar or identical with white blood-corpuscles are also found in the lymph, chyle, in the lymphoid tissue, in the marrow of bones, and in pus; all these, including the white blood-corpuscles, are known under the name of *leucocytes.*

Leucocytes have certain characteristic physiological properties, which *Max Schultze, Davaine, Metschnikoff,* and others observed and described; these properties are amœboid movement, phagocytosis, and chemotaxis.

The *amœboid movement* is a mode of locomotion peculiar to the amœba. White blood-corpuscles normally do not exhibit this property in the circulating blood, but they can be seen to pass along as spherical cells in the current of blood. It has been observed, however, that in inflammatory conditions the white blood-corpuscles migrate, by means of this peculiar movement, through the walls of the capillaries and through the tissues to the area of inflammation.

Phagocytosis is a property possessed by leucocytes by which they can take up and absorb substances such as pigment, micro-organisms, bacteria, many pathogenic products, and products of retrogressive processes in the tissues. *Metschnikoff,* who studied this function, termed it phagocytosis, and the cells possessing it, phagocytes. It is believed that in the resorption of the deciduous teeth phagocytes take up the granules of the inorganic matter.

Chemotaxis, or *chemotropimus,* is another characteristic property possessed by the leucocytes. It consists in their peculiar tendency to migrate toward the seat of certain substances, particularly toward the seat of products of degenerative processes and pathogenic micro-organisms. For instance, if staphylococci are introduced at some part of the body, the leucocytes migrate toward them by virtue of their property of amœboid movement, and, having

reached their seat, the phagocytes will take up into themselves the bacteria and tend to destroy them.

It is believed that white blood-corpuscles also take part in the coagulation of the blood. When blood is taken from the circulation it will be found that a great portion of its white corpuscles are destroyed ; and it is believed that certain substances in these have a fibrin-forming quality. In certain infectious diseases, such as septicæmia, so-called *thrombi* are found within the veins. These are formed from coagulated blood, and are believed to be the result of a destruction of white corpuscles and subsequent coagulation of blood within the vessels.

C. The Blood-Plates.

The blood-plates or plaques are small, pale discs averaging in size from $\frac{1}{350}$ to $\frac{1}{300}$ of a millimetre in diameter. They have no characteristic structure. Their number is about 200,000 to 250,000 in one cubic millimetre of blood. It is believed that they are an important factor in the fibrin formation in coagulating blood.

D. The Elementary Granules.

In the blood there are also a number of minute, irregular granules which are thought to be protoplasmic masses resulting from the breaking-up of red and white corpuscles in the blood.

II. THE PLASMA.

The blood-plasma, or *liquor sanguinis*, is the fluid medium in which the histological elements already described float. Plasma is a thickish, sticky fluid. Its reaction is neutral, its color yellowish, and its specific gravity 1027.

The composition of plasma is as follows :

1. Water, 90 per cent.
2. Inorganic salts, 0.85 per cent. These are sodium

chloride, sodium sulphate, sodium carbonate, sodium phosphate, calcium phosphate, and magnesium phosphate.

3. Fats, 0.1 to 0.2 per cent—namely, olein, palmetin, stearin, cholesterin.

4. Grape sugar, traces of which are contained in the blood of the hepatic vein.

5. Excrementitious substances, such as urea, kreatin, uric acid, etc. These are more abundant after the taking of nitrogenous foods.

6. Albuminoid substances, 8 to 10 per cent; among these are serum-albumin, serum-globulin, fibrinogen. Of these about 0.2 per cent are fibrin-forming substances.

7. A yellowish coloring-substance.

8. Gases—namely, oxygen, nitrogen, and carbon dioxide.

The Gases of the Blood.

It is an established fact that between the particles of a porous substance and between the particles of gases there exists an affinity which manifests itself in the absorption of gases by porous solids. This same affinity exists between the particles of liquids and of gases. It is, for instance, well known that water absorbs oxygen from the air. The volume of gas which substances absorb is equal under various conditions of pressure, but an increased pressure increases the quantity or weight of the gas in that volume. It follows, therefore, that the quantity of gas absorbed by a substance can be diminished by diminishing the outside pressure of that gas. This is accomplished by means of an air-pump. Absorbed gases can also be removed by heat, which decreases the absorbing power of the substance holding the gases.

The phenomenon of the diffusion of gases is also used to determine the character of the absorbed gas or gases.

The law of the diffusion of gases is, that when gases are brought together which do not chemically combine, their molecules will diffuse, independent of their respective

weights, until an equal mixture of the gases has taken place. This diffusion of gases also takes place through porous solids, and between the molecules of gases absorbed in liquids and those not absorbed.

It follows, therefore, that gases absorbed by a liquid can be removed from it by bringing the substance in contact with another gas, when, according to the law of the diffusion of gases, the particles of gas absorbed in the substance will mix with the particles of the gas surrounding the substance until an equal mixture of the two gases has taken place.

The gases contained in the human blood are oxygen, nitrogen, and carbon dioxide; they are partially absorbed by, and partially chemically combined with, substances of the blood.

The *oxygen* contained in arterial blood is about 17 per cent by volume; the quantity in venous blood is much less. Only a small quantity of oxygen is absorbed by the plasma of the blood. This quantity is equal to the amount of oxygen which distilled water would absorb at a pressure equal to that of the oxygen in the air of the lungs heated to a temperature equal to that of the blood.

The greater portion of the oxygen of the blood is combined chemically with the hæmoglobin of the erythrocytes. One gramme of HO will combine with 1.5 cubic centimetres of oxygen at ordinary atmospheric pressure.

The oxygen can all be removed from the blood by the use of the air-pump, by heat, and by treating with other gases. Chemical processes may also be employed, but are not necessary, because the combination of the oxygen with HO is but a very loose one.

The quality and quantity of the gas eliminated from the blood are determined by applying the common chemical tests for oxygen.

Human blood contains about 1½ per cent of *nitrogen* (by volume); this is mostly absorbed by the plasma, but a

small portion is held in chemical combination in the corpuscles, etc.

Carbon dioxide (CO_2) is also contained in the blood, partially in simple solution, to a greater extent in chemical combination with the substances contained in the plasma, particularly with the carbonates, and also with the red and white blood-corpuscles. Arterial blood contains about 30 per cent (by volume), venous blood a larger percentage, of carbon dioxide.

The total quantity of blood in the human body is about $\frac{1}{13}$ to $\frac{1}{15}$ of the body weight.

Arterial blood differs from venous blood in the following points:

1. It is bright red.
2. It is generally one degree warmer.
3. It contains more O and less CO_2.
4. It contains more water, more fatty matter, more sugar, and more salts.
5. It contains a smaller quantity of red corpuscles.
6. It contains less excrementitious substances, such as urea, etc.

The uses of the blood may be enumerated as follows:

1. To act as a medium for the reception of the materials intended for the nutrition of the body.
2. To act as a medium by which the nutritive materials are conveyed to, and the waste materials from, the tissues.
3. To act as a medium for the exchange of gases in the lungs and in the tissues.
4. To distribute warmth to all parts of the body.
5. To give pliability to the texture of many tissues.
6. To furnish the secreting glands with the materials required for their secretion.

In order that the blood may properly serve its uses it must contain its many ingredients in proper quantity and quality, and, since many pathological conditions depend upon this, it is essential that the clinician be able to test

and examine the quantity and quality of the blood ingredients. The more common methods of examination of the principal blood ingredients I have already mentioned and described; the more complicated tests will be brought to your notice in your practical course in physiological chemistry.

I will only mention at this time some of the pathological conditions which depend upon changes in the quality or quantity of blood constituents.

Plethora, or polyæmia, is an increase of the total amount and of the constituents of the blood. It is caused mainly by an excessive nutritive process. This condition is recognized by an increased blood-pressure, full veins, red color, congestion, and a hard, strong pulse. The condition becomes dangerous when the blood-pressure is so increased that a rupture of the wall of a blood-vessel may occur.

Polyœmia serosa is a condition in which the watery part of the blood is increased; it occurs often in diseases in which the secretory function of the kidneys is interfered with.

Leukœmia is the excessive increase of white blood-corpuscles, and, according to the seat of the increase of the leucocytes, we classify it as myelogenetic, splenic, and lymphatic leukæmia.

Anœmia is a condition characterized by a diminution of HO.

Progressive pernicious anœmia is a condition characterized by the impairment of the functions of the organs in which the blood constituents, principally the erythrocytes, originate.

Chlorosis is a condition in which we find a lack of development and weakness in the circulatory apparatus and a disturbance of the blood-forming organs.

Besides these pathological conditions mentioned, there are many others dependent upon a change in form, size, and function of the blood-corpuscles, or upon an increase

or decrease of the constituents of the plasma. We find, for instance, conditions in which the albuminous matter of the plasma is increased or decreased, those in which the fatty matter is increased, and those in which the carbohydrate matter is increased. In many febrile diseases an increase of fibrin-forming substances has been observed. Of late considerable importance has been attached to the fact that, in many diseases depending upon bacteria, the characteristic bacteria of those diseases have been detected in the blood. I will mention here only the micro-organism of malarial fever (plasmodium) and that of typhoid fever.

From the foregoing it will be clear to you that the examination of the blood is an important point in the diagnosis of many diseases, and that in order to understand or detect any changes in the blood it is essential to fully understand the composition, physical and chemical properties, and the histology and physiology of normal blood.

LECTURE VIII.

THE COAGULATION OF THE BLOOD.

In my last lecture I finished the description of the normal human blood, and, for a better understanding of the subject of this lecture, I will repeat that normal circulating blood consists of the plasma, or liquor sanguinis, and of the blood-corpuscles suspended in it. The coagulation of the blood is a phenomenon consisting in the separation of the blood-constituents into a clot and the serum.

The *clot* is a soft, jelly-like mass, reddish-white in color, composed of the blood-corpuscles held together by a network of delicate fibrillæ.

The *serum* is the plasma minus the fibrinogen ; its specific gravity is 1028, and its alkalinity is about one-half that of the blood; it is a clear, almost colorless fluid.

Process of Blood Coagulation.

Circulating blood normally does not coagulate when the inner surface of the blood-vessels is in a normal condition.

When blood is taken from the circulation into some vessel, it will very soon be noticed that the blood separates into two parts—first, a soft, gelatin-like mass which sinks to the bottom and assumes the shape of the vessel; and second, a clear fluid, the serum, covering the gelatin-like mass. In from two to fifteen minutes it can be seen that fine fibrillæ begin to form upon the surface of the gelatin-like mass. In about twelve to fifteen hours it will be found that the whole mass is permeated by these delicate fibrillæ, so that it can be cut ; this is the clot. In conditions where the

process of coagulation is retarded, as it is in the case of febrile conditions, in chlorosis, and in hydræmia, the clot has a whitish surface, due to the fact that the erythrocytes sink to the bottom before the coagulation takes place. This is the case whenever in the blood the specific gravity of the erythrocytes is increased, or when that of the plasma is decreased. These conditions are present in the diseases mentioned above.

The blood-coagulation is therefore due to fibrin formation.

When freshly-drawn blood is beaten with a stick, fibrin can be obtained in the form of delicate fibrillæ, which collect around the stick; blood so treated is termed *defibrinated blood.*

Fibrin consists of delicate elastic fibrillæ. It is insoluble in water and ether, and when treated with hydrochloric acid is transformed into xantonin.

According to *Alexander Schmidt*, fibrin is formed by the union of two constituents of the plasma in the presence of a ferment. These two substances are *fibrinogen* and *fibrinoplastin*; they are both albuminous, belonging to the class of globulins. They are contained in solution in the plasma and do not differ much in their chemical composition.

Fibrinoplastin, also called *serum-globulin* or *paraglobulin*, can be precipitated by the addition of magnesium sulphate; it is soluble in a 10 per cent solution of sodium chloride. Fibrinoplastin is best obtained from serum by precipitating it in the manner indicated.

Fibrinogen is the substance which forms the main mass of the fibrin; it is best obtained from hydrocele fluid and from the serous secretions of the pericardium, the pleura, etc., from which it is precipitated by the saturation of these fluids with sodium chloride. The two fibrin-forming substances are soluble in dilute solutions of alkalies, of sodium chloride, and of hydrochloric acid.

Fibrinogen differs from fibrinoplastin in that the former may be more readily precipitated and dissolved again.

The *fibrin-ferment* is obtained by treating blood-serum with strong alcohol; the resulting precipitate, composed of albumin and the ferment, is dried, pulverized, and then treated with water and filtered; the fibrin-ferment, being soluble in water, passes through the filter and so is separated from the albumin. If solutions of the three fibrin-forming substances are mixed the formation of fibrin will at once take place; the presence of oxygen and sodium chloride is essential for the process; a temperature of about 98.6° is preferable.

The fibrin-forming substances constitute about 0.2 per cent of all the albuminous substances of the plasma. According to *Alexander Schmidt*, the fibrin-forming substances originate mainly in the leucocytes, although fibrinogen, and probably fibrin-ferment, are already contained in solution in the plasma of the circulating blood.

When blood is drawn from the circulation numerous leucocytes are destroyed. The products of this breaking-up dissolve in the plasma, and some of them form the fibrinoplastic substance.

I have already stated in a previous lecture that in certain pathological conditions, such as septicæmia, in which a breaking-down of the leucocytes takes place in the circulating blood, portions of coagulated blood are formed in the veins, called thrombi.

Further observations have revealed the fact that the erythrocytes also have a part in the formation of the fibrin.

Landois has been able to observe the formation of fibrin from the stroma of erythrocytes of mammalia. The fibrin may therefore, in accordance with its origin, be divided into plasma-fibrin and stroma-fibrin. It has been observed that substances which dissolve erythrocytes produce a rapid coagulation of the blood.

The coagulation of the blood is retarded or entirely prevented by:

1. The addition of alkalies, such as ammonia.
2. The addition of saturated solutions of certain salts, such as carbonates, phosphates, sulphates, especially magnesium sulphate.
3. Cold, freezing.
4. High pressure.
5. Addition of acetic acid until an acid reaction is obtained.
6. Increased amount of CO_2.
7. The addition of egg-albumen, of a solution of sugar, of glycerin, of great quantities of water.
8. The addition of pancreatic and diastatic ferments.

Menstrual blood and that of hæmophiles show very little tendency to coagulate.

Conditions hastening the coagulation of blood are:

1. Contact with foreign substances to which the blood can adhere; for instance, threads, needles, wire, etc., introduced into the blood-vessels.
2. Heat.
3. Air.
4. Products of the retrogressive changes of albuminous substances, such as uric acid, leucin, taurin, lecithin, etc.
5. Certain chemicals, mainly acids in small quantities.

Blood does not normally coagulate when circulating, provided the endothelial lining of the vessels is intact; if this is roughened by inflammation or by traumatism, a clot will be deposited upon the roughened surface.

When blood is stagnant in the vessels coagulation does not take place rapidly, but a clot will gradually form in the centre of the vessel where the blood does not come in contact with the epithelial lining.

Before finishing the subject of the physiology of the blood, I will consider a subject to which of late years much attention has been paid. I refer to the serum treat-

ment, which to-day is employed in many diseases—viz., in infections, or such diseases as depend upon the development of specific poisons and micro-organisms such as bacteria.

Blood and the serum of blood possess a germicidal property; that means a property to destroy bacteria. This property of the blood is believed to be due to certain albuminous and mineral ingredients, the removal of which destroys this power of the blood and serum; heat and exposure to light have the same effect.

It has been demonstrated by experiments that individuals are immunized against certain infectious diseases by repeated inoculations with the poison or micro-organisms of such diseases; furthermore, it has been demonstrated that the blood or serum of individuals so inoculated destroys the poison or micro-organisms of the disease. These facts are utilized to-day very extensively not only in the curative but also in the prophylactic treatment of many infectious diseases, such as tuberculosis, diphtheria, hydrophobia, tetanus, etc. For a better understanding I will describe to you the mode of preparation and the use of the diphtheria antitoxin, which now is most exclusively used by every scientific practitioner of medicine in the treatment of that dreadful disease, diphtheria, against which, for so many years, medical science and skill was apparently powerless. The great success of this treatment is shown by the marked decrease in the percentage of deaths from the disease. To-day the health department of almost every large city prepares diphtheria antitoxin, so that even the poorest may reap the benefit of this preparation, formerly so expensive.

The constant observations of the experienced medical inspectors of the Health Department show that the disease can be thus successfully combated in most cases, if used properly and at the right stage of the disease. Indeed, the preparation is frequently used as a preventive

of the disease, in the same way as vaccine virus is used to prevent small-pox. To-day members of a household in which diphtheria has appeared are inoculated with the antitoxin to prevent infection, and observations and statistics show that this is actually accomplished by such treatment.

The discovery of the diphtheria antitoxin is the result of the studies of *Behring*, of Berlin, and of *Pasteur*, of Paris.

To *Dr. H. M. Biggs*, chief pathologist of the Health Department of this city, the credit is due of having created a special department for the diagnosis and treatment of diphtheria, and special laboratories for the preparation of the diphtheria antitoxin, so that, as stated before, the antitoxin may be obtained even by the poorest.

The method of the preparation of the diphtheria antitoxin employed by the Health Department of this city is as follows: Perfectly healthy horses, kept especially for that purpose, are repeatedly inoculated until a condition is obtained where inoculation fails to cause the characteristic symptoms. Blood is then drawn from the immunized animal. The serum of this blood is aseptically prepared in certain strengths, and is the antitoxin as it is used. The strength of the solution is given in antitoxin units.

QUESTIONS AND EXERCISES.

SUBJECT.—*The Physiology of the Blood.*
Lectures VI.–VIII. inclusive.

69. What is the blood ?
70. Why is human blood opaque ?
71. What is the color of human blood ?
72. What is the coloring matter of the blood ?
73. Why is blood light in the arteries and dark in the veins ?
74. What is the specific gravity of the blood ?

75. State conditions in which the specific gravity of the blood is increased and those in which it is decreased.

76. What is the reaction of human blood ?

77. Name some of the conditions which lessen and some which increase the alkalinity of the blood.

78. How would you ascertain the relative alkalinity of the blood ?

79. What is the odor of human blood ?

80. What is the taste of human blood ?

81. Name the morphological elements of the blood.

82. Why is blood considered a tissue ?

83. By whom were the red blood-corpuscles first observed in human blood ? When ?

84. Describe the structure of a red blood-corpuscle.

85. Name the physical properties of red blood-corpuscles.

86. What is the chemical composition of red blood-corpuscles ?

87. Give the measures of a red blood-corpuscle.

88. State the physiological functions of the red blood-corpuscles.

89. What is hæmoglobin ? Describe it.

90. Give the composition of HO.

91. What is hæmatin ? Hæmatoidin ? MetHO, O–HO, and CO–HO ? State where and under what condition they are found in the human body.

92. What is the usual difference in shape between the red corpuscles of the blood in the mammalia and those of the ovipara ?

93. Mention some of the mammalia which do not have circular, disc-like red blood-corpuscles.

94. Describe the process by which you can obtain hæmatin crystals from old blood-stains.

95. What is the number of red blood-corpuscles in 1 cubic millimetre of human blood ?

96. Describe the process of counting the red blood-corpuscles.

97. Name the origin of the red blood corpuscles.

98. State the average duration of life of a red blood-corpuscle.

99. Where are the red blood-corpuscles destroyed in the body? Mention facts sustaining your statement.

100. Name liquids in which red blood-corpuscles can be preserved.

101. What is the quantity of HO in the blood, and how can this be determined?

102. How much iron, by weight, does HO contain?

103. What is CO? What takes place when it is inhaled, and what are the symptoms of CO poisoning?

104. Give the treatment for CO poisoning.

105. When is transfusion of blood required? Mention objections to this operation.

106. Describe the Abbe-Zeiss counting apparatus.

107. Describe the shape, size, and structure of a white blood-corpuscle.

108. What is meant by eosinophile, basophile, and neutrophile protoplasm granules in the white blood-corpuscles?

109. Give the chemical composition of white blood-corpuscles.

110. What is the number of white blood-corpuscles (*a*) at different ages, (*b*) in different sexes, and (*c*) in the different locations.

111. Mention bodily states in which the number of white blood-corpuscles is increased, and those in which it is decreased.

112. Name the process of counting white blood-corpuscles.

113. Give the origin of the white blood-corpuscles in the body.

114. What are leucocytes?

115. What are the physiological properties of leucocytes?

116. What is chemotaxis?

117. What is phagocytosis?
118. What are the blood-plaques? Describe them.
119. What are the elementary granules seen in the blood?
120. What is liquor sanguinis?
121. Give the composition of plasma.
122. What is the reaction and specific gravity of the plasma?
123. Name the gases of the blood. How and where are they contained in the blood, and how can they be eliminated from it?
124. What is the total quantity of blood in the human body?
125. What are the differences between arterial and venous blood?
126. What are the uses of the blood?
127. Name some bodily states in which ingredients of the blood are increased or decreased.
128. What is meant by the coagulation of the blood?
129. What is a clot?
130. What is the serum?
131. What is the composition of serum?
132. Describe the process of blood-coagulation.
133. To what is the coagulation of the blood due?
134. Name the fibrin-forming substances.
135. How can the fibrin-forming substances be obtained?
136. How is blood defibrinated?
137. State what part the corpuscles take in blood-coagulation, and mention facts sustaining your statement.
138. What favors and what retards blood-coagulation?
139. What is a hæmophile?
140. What do you understand by the serum theory, and upon what peculiar property of the blood or serum is it based?
141. Describe the preparation and use of the diphtheria antitoxin.

142. What do you understand by toxins?
143. What are bacteria?
144. What do you understand by immunization?
145. Name conditions in which bacteria are found in the blood.

LECTURE IX.

THE CHEMICAL INGREDIENTS OF THE HUMAN ORGANISM.

It has been found that about seventeen of the sixty-seven or seventy chemical elements exist in the fluids and tissues of the human organism. These seventeen elements are: oxygen, carbon, hydrogen, nitrogen, calcium, phosphorus, sodium, potassium, silicon, magnesium, chlorine, fluorine, sulphur, iron, manganese, copper, and aluminium.

They are found in the human body in the following approximate proportion: oxygen, 720 in 1,000 parts; carbon, 135; hydrogen, 90; nitrogen, 25; calcium, 10; phosphorus, 1; sodium, 1; and the remaining ten elements, 8 parts. These elements exist in the human body in the form of chemical compounds, with the exception of oxygen and nitrogen, which exist in a free state.

The chemical substances, elementary or compound, which normally exist in the body, and which can be extracted from it in the form in which they exist, are known as the *proximate principles.*

The proximate principles are divided into (1) Inorganic, (2) Organic.

I. THE INORGANIC PROXIMATE PRINCIPLES.

The substances of this class originate in the inorganic world. They are generally taken into the body with the food, drink, or air, but sometimes they are the result of chemical processes in the body; they are eliminated generally in their own form with the secretions.

The substances of this group are: 1, water; 2, inorganic salts; 3, inorganic acids; 4, gases; 5, metals.

1. *Water* constitutes 58.5 per cent of the whole organism and is found in all fluids and tissues. It serves to render the tissues soft and pliable, and also acts as a medium for the suspension or solution of the fluid ingredients of the body. The soft tissue of the kidneys has the greatest percentage of water—namely, 82.5 per cent; bone contains 22 per cent, teeth 10 per cent, and the enamel of the teeth 0.2 per cent.

The water in the body is generally taken in as such with the food and drink, but a small amount is formed within the body. Water is eliminated from the body, as such, through the kidneys, skin, and with the fæces.

2. *The inorganic salts* contained in the body are the chlorides of sodium and potassium, the carbonates of sodium and potassium, the phosphates of sodium and potassium, the sulphates of sodium and potassium, the phosphates and carbonates of magnesium, and, besides these, small quantities of fluoride and carbonate of calcium, chloride of ammonium, and bicarbonate of soda.

Sodium chloride is probably contained in the body in a greater quantity than any other salt; this is estimated to be 110 grammes in the adult. It is taken in as such as an essential constituent of the food, and is excreted in its own form with the urine and the sweat; the quantity thus discharged in twenty-four hours is estimated to be 15 grammes. This salt is contained in almost all fluids, tissues, and secretions of the body; its main use is to favor certain physical processes, such as solubility, absorption, osmosis, etc.

Potassium chloride is also contained in many tissues and fluids of the body, but the total quantity is less than that of sodium chloride. In muscle and in milk it is more abundant than the former salt. Its uses in the organism are the same.

The *sulphates* are taken in as such with the food, but to some extent they are formed within the body as a product of the decomposition of albuminoid substances. They are

eliminated chiefly with the urine. They exist only in small quantities, principally in the urine, hair, and nails.

The *phosphates* are more abundant. The so-called alkaline phosphates are the salts which maintain the reaction of the many alkaline fluids in the body. The neutral phosphates constitute part of the inorganic basis of the hard tissues and serve to maintain their rigidity. These salts are taken into the body as such, and are eliminated with the urine, sweat, and fæces.

The *carbonates* are found in the same tissues as the phosphates, and they also serve the same purpose. The salts of this class predominate in the herbivora, whereas in the carnivora the phosphates are the more numerous.

The other salts mentioned as existing in the body are more incidental. They are found in the tissues, fluids, and secretions, and are sometimes taken in as such with the food and drink, and sometimes are the result of chemical processes within the body.

3. *Inorganic acid.* In the human organism hydrochloric acid is found in a free state in the gastric juice.

4. *The gases.* In a previous lecture I stated that certain gases—namely, oxygen, nitrogen, and carbon dioxide—exist in the blood. Besides this we find CH_4, NH_3, and H_2S, traces of which are absorbed from the intestinal tract, in which they form as a result of the decomposition of the food residue.

5. *The metals* existing as such in the body are iron, manganese, and aluminum. In the liver and bile traces of copper, together with the other metals mentioned, have also been found. They often form ingredients of certain bile stones. Iron constitutes 0.42 per cent of the hæmoglobin of the blood.

II. THE ORGANIC PROXIMATE PRINCIPLES.

The substances of this group are chemical compounds

which originate and exist only in living organisms. These substances do not originate or exist in the inorganic world.

The vegetable organism is capable of producing organic substances from inorganic material. The plants take from the soil, air, and water, inorganic material, and transform it into the organic material composing their tissues.

The animal organism must receive for its nutrition organic material already formed in other organisms, in order to be able to form and reproduce its own organic material. The animal organism, therefore, is not capable of producing organic substances from inorganic material.

The organic proximate principles are divided into (1) organic non-nitrogenized and (2) organic nitrogenized substances.

1. *The Organic Non-nitrogenized Proximate Principles.*

The members of this class are composed of oxygen, hydrogen, and carbon, united in varying proportions to form compounds which have a simple chemical constitution.

They are again subdivided into two groups—namely, into (*a*) *carbohydrates* and (*b*) *hydrocarbonates.*

(*a*) *The Carbohydrates.*—The members of this group are distinguished from those of the second group in that the hydrogen and oxygen are always present in them in the proportion in which they are found in water. This group includes the starches and sugars.

The carbohydrates of the plants are formed within these from inorganic material, and the first organic substance so formed is starch, from which all other organic compounds of plants are finally developed.

The green plants—namely, those containing chlorophyll (the green coloring matter of the plants)—are capable, under the influence of solar light, of taking up carbonic dioxide from the air, and water from the soil, and transforming them into starch; during this process oxygen is liberated

and exhaled by the plant. The process can be expressed by a chemical equation as follows:

$$6CO_2 + 5H_2O = C_6H_{10}O_5 + O_{12}.$$

Starch is contained in many plants used as food—for example, in wheat, rye, oats, barley, rice, corn, peas, beans, potatoes, etc.

Plants containing a large percentage of carbohydrate material are called amylaceous plants. The starch is contained in the plants in the form of granules. Starch granules consist of a substance called *granulose*, embedded in a dense, firm substance, the *cellulose*. Granulose is soluble, cellulose is insoluble, in water.

The chemical formula for starch is $C_6H_{10}O_5$; with iodine it forms a chemical compound, the iodide of starch; this has an indigo-blue color and is readily formed when iodine comes in contact with starch; iodine is, for this reason, used as a test to detect the presence of starch.

All organic substances in plants are the result of chemical changes which take place under the varying conditions of temperature, climate, and soil.

The carbohydrate substances existing in the animal body are formed mainly from carbohydrate material taken in as such with the food. The carbohydrates found in the fluids and tissues of the human body are dextrin, glycogen, glucose, and lactose or inosit. *Dextrin* is a carbohydrate substance which is formed in the alimentary canal as the result of the action of the so-called diastatic ferments of the digestive juices upon starchy foods. Dextrin is a substance isomeric with starch—that is, it has the same chemical formula, but differs in its physical properties. It has a brownish color and is soluble in water; with iodine it gives a rose-red color. Dextrin can be formed from starch by heating, by the addition of dilute sulphuric acid, and by the addition of diastatic ferments—namely, the diastase of plants and the diastatic ferments of the animal

digestive juices. *Glycogen* is a carbohydrate substance which is isomeric with starch and dextrin. It has the same chemical composition as these—namely, $C_6H_{10}O_5$—but differs in its physical properties; it is soluble in water; with iodine it gives a dark-brownish color. Glycogen is also called animal starch; it is produced in the liver by a process of dehydration of glucose. *Glucose*, also called *dextrose* or *grape-sugar*, is that variety of sugar which is found in ripe grapes and in the juices of many sweet fruits and flowers; also, to some extent, in honey. In the animal body small portions of this are found in the blood, muscle-tissue, liver, chyle, and urine. Glucose in the animal body is the result of the continued action of diastatic ferments upon carbohydrate foods. In plants glucose is formed from starch under the influence of climate and solar heat; it can be produced artificially by boiling starch with dilute sulphuric acid. The transformation of starch into glucose consists in the assumption of one molecule of water. The process may be expressed by the following chemical equation:

$$C_6H_{10}O_5\text{(starch)} + H_2O\text{(water)} = C_6H_{12}O_6\text{(glucose)}.$$

In a disease called *diabetes mellitus* the production of this variety of sugar in the animal body is so excessive that the sugar is eliminated with the urine. Constant symptoms of this disease are great thirst and great desire to eat; passing of large quantities, often gallons, of urine daily; emaciation, dry and itching skin, and the appearance of peculiar skin eruptions and ulcers. A positive diagnosis is made by an analysis of the urine, and in order to make such analysis it is essential to be familiar with the more common tests and to determine the presence of glucose. The tests most frequently used are the alkali test, Trommer's test, and the fermentation test.

The *alkali test* used to determine the presence of glucose is as follows: To the suspected solution a few drops of a solution of potassium hydrate are added and the whole

heated; the presence of glucose is indicated by a brown color. This test, however, is not positive, because other incidental ingredients of urine give a similar reaction.

Trommer's test for the determination of the presence of sugar is as follows: To the suspected solution first an alkaline solution, such as sodium hydrate, is added to render it alkaline, then a few drops of a solution of cupric sulphate are added, and the whole is now heated; if glucose is present a red color will quickly be produced, and, on standing, a brick-red precipitate will form. This test is based upon a quality of the glucose which consists in its power to reduce certain metallic compounds under favorable conditions. In this test the soluble cupric sulphate is reduced to a suboxide of copper, which is a brick-red insoluble powder. The solutions used for this test, as prescribed by *Fehling*, are as follows:

(*a*) The alkaline solution: 150 grammes of potassium tartrate are dissolved in 500 cubic centimetres of a 10 per cent solution of sodium hydrate.

(*b*) The sulphate of copper solution: 34.5 grammes of cupric sulphate are dissolved in 200 cubic centimetres of distilled water. These two solutions are mixed, and distilled water is added to make 1,000 cubic centimetres. One cubic centimetre of this solution contains a quantity of cupric sulphate, which is reduced to a suboxide of copper by 0.0005 of sugar. With this solution it is possible, therefore, to make a qualitative, and also approximately a quantitative, examination for sugar.

The *fermentation test* is based upon the fact that glucose is decomposed into carbon dioxide and alcohol by yeast, a vegetable ferment. If to a fluid containing glucose, yeast is added, bubbles of gas will soon be seen to rise from the surface of the fluid ; this gas is carbon dioxide. The little apparatus used for this purpose is so arranged that the gas is collected in the upper closed portion of the glass tube,

and from the quantity so collected in a certain time the quantity of glucose can be calculated.

Levulose, or inverted sugar, is found in the alimentary canal, where it is formed by the action upon carbohydrate foods of a ferment of the succus entericus, called invertin. It also exists as such in the juice of many fruits. It is isomeric with glucose and rotates the rays of polarization toward the left. It rarely occurs in the urine in diseased conditions.

Lactose, or milk-sugar, is an important constituent of mother's milk. Its chemical formula is $C_{12}H_{24}O_{12}$. It is not as sweet and not as soluble as glucose, but it responds to the same tests. It is found in the urine of nursing mothers, being absorbed from the excess of milk in the mammary glands. During its fermentation lactic acid is formed.

Inosit is a sugar contained in muscle and in many other tissues of the body; it is also contained in plants, principally in the leguminous plants, such as beans.

Inosit, $C_6H_{10}O_6$, is insoluble in alcohol, has a sweet taste, and does not respond to the tests generally applied to glucose.

In pathological conditions it occurs in the urine and the fluid of echinococcus cysts, together with glucose.

The carbohydrate substances in the body are tissue-forming and heat-producing materials; they are eliminated from the body, not in their own form, but after undergoing processes of decomposition.

(*b*) *The Hydrocarbonates.*—The members of this group contain carbon in abundance, and hydrogen and oxygen not in a proportion to form water. To this class belong the fats and oils and the fatty acids. The fats and oils existing in the human body are the palmitin, stearin, olein, butyrin, caprolin, caprylin, caprinin, myristin, and cholesterin.

Olein, *palmitin*, and *stearin* are the substances constituting the fat of the animal body ; they also exist in many fruits and nuts. They are insoluble in water, freely soluble in ether. At ordinary temperatures olein is liquid, palmitin and stearin solid. In the animal body they are always combined and exist in a liquid form ; palmitin and stearin solidify after death.

Butyrin, *caprolin*, *caprylin*, *caprinin*, and *myristin* exist in the milk and constitute the fatty substances of butter. *Cholesterin* is a substance belonging to this class; it exists in small amounts in the blood, bile, and in many other tissues ; it constitutes a great part of the so called gall-stones.

The fatty acids are : 1, oleic; 2, stearic; 3, palmitic; 4, butyric; 5, caproic; 6, capric; 7, formic; 8, acetic; 9, propionic ; 10, sebacic ; 11, leucic ; 12, lactic ; 13, oxalic ; 14, benzoic; 15, carbolic.

Of these, numbers 1 to 6 are found in small quantities in the alimentary canal as the result of the breaking-up of the fats into glycerin and fatty acids in the presence of certain ferments. The fatty acids unite with alkalies to form soap. Numbers 7 to 11 inclusive are present in sweat and in the fatty secretions of the skin.

Lactic acid exists in the juice of the muscle-tissue, and at times it is found as a product of decomposition in the alimentary canal.

Oxalates are found in the urine after the taking of certain foods and drinks.

Traces of *benzoic* and *carbolic acid* (the so-called *aromatic* acids) are sometimes found in urine.

The hydrocarbonates in the animal body are, like the carbohydrates, tissue-forming and heat-producing substances. They are eliminated only to a small extent as such with the excretions, viz., with the sweat, urine, and fæces ; the greater number of these substances undergo chemical changes in the body.

LECTURE X.

THE CHEMICAL INGREDIENTS OF THE HUMAN ORGANISM (*continued*).

In my last lecture I finished the description of those organic ingredients of the animal body which contain no nitrogen. To-day I will take up those which contain nitrogen. They are known as the

2. *Organic Nitrogenized Proximate Principles.*

The following substances belong to this class: (*a*) the albuminous substances; (*b*) the albuminoid substances; (*c*) the ferments; (*d*) the coloring substances; (*e*) the products of the decomposition of the albuminous and albuminoid substances in the animal body.

(*a*) The Albuminous Substances.

The substances of this class are also called the *proteins*. They are composed of carbon, oxygen, hydrogen, nitrogen, and sulphur. They constitute the main portion of the protoplasm of the tissues and are introduced into the body with the food. These substances originate in the plants and develop in them from non-nitrogenous matter by the taking up of sulphur and nitrogen from the sulphates and nitrates of the soil.

The exact chemical composition of the albuminous substances is unknown. The elements composing them exist in the following approximate proportions: carbon, 49 to 54 per cent; oxygen, 20 to 23 per cent; hydrogen, 6 to 7 per cent; nitrogen, 14 to 17 per cent; sulphur, 0.8 to 2 per cent.

The albuminous substances have in common certain characteristic properties. They are all non-crystallizable,

non-diffusible, coagulable, putrefactive, hygroscopic, and they all undergo catalytic transformations in the presence of ferments.

Albuminous substances are soluble in strong acids and alkalies, but also undergo chemical changes. Some are soluble in water, saline solutions, and in dilute acids or alkalies. Most of them are insoluble in alcohol and ether. These substances can rarely be obtained in a pure state, but can be precipitated from their solutions in an amorphous condition.

The chemical reactions generally employed as tests for albuminous substances are:

1. The *Xantho-proteic Reaction.*—When albuminous substances are coagulated by the addition of nitric acid, and heat is applied, a yellowish color is produced, which, upon the addition of ammonia, becomes a dark-orange color.

2. *Millon's Reaction.*—When to a solution containing albuminous substances Millon's reagent (a solution of nitrites and nitrates of mercury) is added and the solution is then heated, a reddish-pink color is produced.

3. When to a solution containing albuminous matter ferrocyanide of potassium and acetic acid are added, a white precipitate is formed; the same result is obtained when the solution is boiled with acetic acid and sodium sulphate.

4. When a solution containing albuminous matter is boiled with potassium hydrate and a little of a cupric sulphate solution is added, a deep purple color is produced.

5. When treated with iodine, albuminous substances assume a yellow-brown color.

The albuminous substances are divided into the following groups: the true albumins, the derived albumins, the globulins, the peptones and albuminoses.

The *true albumins* are the *egg albumin* and the *serum-albumin.* The latter is contained in the blood, lymph, and

chyle, in the synovial and serous fluids, and in the parenchymatous juice of the tissues. In certain physiological and in many pathological conditions it is found in the urine.

The *derived albumins* are the *acid-* and *alkali-albumins.* Both are formed when albuminous substances come in contact with acids or alkalies respectively. In the animal body they are formed in the alimentary canal during digestion, by the presence of the acid or alkaline digestive juices.

Syntonin is an albuminous substance resembling acid-albumin; it is found in muscle-tissue.

Alkali-albumins are also termed *albuminates.*

The *globulins* are the *globulin* or *crystallin* of the lens of the eye, the *myosin* contained in muscle-tissue, the *serum-globulin*, the *fibrinogen* contained in the blood, and the *casein* contained in the milk. These substances are insoluble in water, but soluble in weak saline solutions.

The peptones and albuminoses. The *peptones* are formed by the action of the digestive juices in the alimentary canal upon albuminous and albuminoid substances; the change they undergo renders them diffusible.

Besides the tests already mentioned, the so-called *Biuret reaction* is used to detect the presence of peptones. This consists in the addition to the suspected solution of a solution of cupric sulphate and potassium hydrate; heat is applied, and a reddish discoloration indicates the presence of peptones.

Albuminoses are the intermediate products of the change of albuminous and albuminoid substances into peptones. Albuminoses are also termed *propeptones.*

(*b*) The Albuminoid Substances.

The substances of this class resemble the albuminous substances as regards their chemical composition; not all of them contain sulphur. They possess the same general chemical properties, and the products of their decomposi-

tion resemble those of the decomposition of albuminous substances. It is believed that these are formed from the albuminous materials by a synthetical process. The albuminoid materials probably do not possess the same physiological value as the albuminous materials. They exist in the animal body in a liquid, solid, or semi-solid form, and constitute the basis of many tissues, such as the connective tissues, the bones, nails, hair, mucous membranes, etc.

The substances belonging to this group are: *Callogen*, contained in the bones, tendons, ligaments, cartilages, etc. When boiled it yields glue.

Chondrin, contained in the cartilages; on boiling, it also yields a gelatinous substance.

Elastin, contained in elastic tissue.

Keratin is the substance which is obtained when horny tissues—such as nails, hair, and epidermis—are treated with substances which extract the other soluble materials from these tissues.

Mucin is contained in the mucous and other slimy secretions.

The *protonuclein*, which forms the larger portions of the cell-nuclei, is also classed in this group; it is an organic nitrogenous substance containing phosphorus.

Hæmoglobin, the coloring matter of the blood, is also to be considered an albuminoid substance; it is composed of albumin and hæmatin.

(*c*) The Ferments.

Ferments are substances which produce chemical changes in other substances with which they come in contact. They are divided into the organized and into the non-organized ferments.

The *non-organized ferments*, or *enzymes*, are those which by their mere presence produce changes in other substances without undergoing any changes themselves. Very small amounts are capable of producing these changes in large quantities of other substances. Temperature influ-

ences this peculiar property in such a manner that cold and heat retard and destroy it, whereas a medium temperature is most favorable to it. The enzymes have an unknown chemical constitution, but resemble the albuminoids in their combination; they do not respond to the same chemical tests as these.

The unorganized ferments, or enzymes, existing in the animal body are:

1. The *amylolytic ferments* are those which produce changes in carbohydrate substances. These are: the *ptyalin* of the saliva, the *amylopsin* of the pancreatic juice, the *invertin* of the intestinal juice. In the blood, lymph, chyle, milk, urine, and in the liver, traces of an amylolytic or diastatic ferment exist.

2. The *proteolytic ferments* are those which produce changes in albuminous and albuminoid substances. These are the *pepsin* of the gastric juice, the *trypsin* of the pancreatic juice, a proteolytic ferment of the intestinal juice.

3. Ferments acting upon fats, the *steapsin* of the pancreatic juice.

4. Milk-curdling ferments, existing in the gastric juice, pancreatic juice, and, in traces, in the urine.

5. The *fibrin-ferment*, existing in the blood, plasma, lymph, and serous fluids.

The *organized ferments* are not constituents of the animal body, but they are taken in with the food and drink. In the alimentary canal they take part in many of the chemical processes. The organized ferments are vegetable micro-organisms or bacteria. To this class belong:

The *bacterium lactis*, which decomposes sugar into lactic acid, etc.

The *saccharomyces*, which decompose sugar into alcohol and carbon dioxide.

The *bacteria of putrefaction*, which are principally found in the lower part of the intestinal canal, where they cause a decomposition of substances and the production of fetid gases. Besides these, certain bacteria find entrance into the

animal body, which, by their presence, produce pathological conditions. These are known as *pathogenic bacteria.*

(*d*) The Coloring Matters.

The substances of this class are nitrogenous. They are considered to be derivatives of the albuminous and albuminoid materials of the body. They are, almost all of them, crystallizable; a few of them can be obtained only in an amorphous condition. These substances are contained in many fluids and tissues of the body, partly in solution, partly deposited in the form of amorphous granules in the cells of the tissues.

The coloring matters existing in the human body are:

1. The coloring matter of the blood—viz., the *hæmoglobin.*

2. The coloring matters of the bile—the *bilirubin*, the *biliverdin*, the *biliprasin.*

3. The coloring matters of the urine—*urochrome*, *urobilin*, *indigo blue.*

4. The pigments of the skin, iris, choroid, hair, and epidermis—the *melanin.*

(*e*) The Products of the Decomposition and Disintegration of the Albuminous and Albuminoid Substances.

The substances of this class are derivatives of NH_3, resulting from the dissimilating metamorphosis of the albuminous and albuminoid substances. These products belong to the group of chemicals known as amines and amides.

Amines are those substances in which atoms of the H of the NH_3 molecule are replaced by alcohol radicals.

Amides are those in which atoms of the H in the NH_3 molecule are replaced by an acid radical.

The substances belonging to this class are: *Leucin*, found in the tissues of many organs, as in the brain, lungs, liver, etc. It is also formed in the alimentary canal during the pancreatic digestion.

Tyrosin is always found in company with leucin; it is also formed during the pancreatic digestion.

Glycocoll, *glycin* or *amido-acetic acid*, is not found free in the animal body, but exists in the glycocholic acid of the bile and in the hippuric acid of the urine.

Kreatin or *kreatinin*. Kreatin is found principally in the juice of the muscles, but also in many other fluids of the body. Kreatinin exists in the urine.

Taurin is formed as a product of the decomposition of taurocholic acid; it is found in small quantities in the lungs, muscles, and kidneys.

Xanthin and *hypoxanthin* are contained in small quantities in the lungs, spleen, and in other tissues.

Uric acid is contained principally in the urine, generally in combination in the form of salts.

Hippuric acid is found in small quantities in human urine, in larger amounts in that of horses.

Urea is the main organic ingredient of human urine; it is also found in small quantities in the blood and the lymph. Urea is the final product of the decomposition of the albuminous and albuminoid substances.

Indol and *skatol* are two malodorous products of the putrefaction of albuminous and albuminoid substances in the intestinal canal.

Lecithin, *protagon*, *neurin*, and *cerebrin* are those nitrogenous substances which are not found as such in the excretions, but are believed to be products of the disintegration of albuminous and albuminoid substances in the body. Lecithin, protagon, neurin, and cerebrin are contained principally in the substance of the brain and nerve tissue. They all, with the exception of cerebrin, contain phosphorus.

Besides the substances of this class above enumerated, there are probably many others which are merely intermediate products of the final decomposition and splitting-up of the albuminous and albuminoid substances in the body.

In my description of the chemical ingredients of the human body, I have dwelt only in a general way on their physical and chemical properties.

I have avoided dwelling at length on these points, that I might not conflict with the instruction which you will receive from your professor of chemistry in the course in physiological chemistry which forms part of the curriculum of the senior year. A practical demonstration of these substances, together with a practical study of their chemical and physical properties, will certainly aid you more than mere theoretical description.

With this my tenth lecture, ladies and gentlemen, I finish with the subjects a study of which I consider essential as introductory to physiology. A study of the histology of the elementary tissues and their physiological properties is essential for the study of the organs of the body and their physiology. As most physiological processes are due to chemical and physical changes, it is necessary to know the ingredients of the animal body and their chemical relations.

For the purpose of a better understanding I have drawn up the following schedule of the classification of the proximate principles which I have adopted :

I. Inorganic substances.

1. Water.
2. Inorganic salts.
   Chlorides of sodium and potassium.
   Phosphates of sodium, potassium, and magnesium.
   Carbonates of sodium, potassium, and magnesium.
   Sulphates of sodium and potassium.
   Chloride of calcium.
   Carbonate of calcium.
   Chloride of ammonium.
   Bicarbonate of sodium.

3. Inorganic acids.
   Hydrochloric acid.
4. Gases.
   O, N, CO_2, CH_4, NH_2, H_2S.
5. Metals.
   Iron, Aluminium, Copper (Lead ?).

II. ORGANIC SUBSTANCES.

(A) *Non-nitrogenous.*

(*a*) The carbohydrates.
1. Dextrin.
2. Glucose.
3. Glycogen.
4. Levulose.
5. Lactose.
6. Inosit.

(*b*) The hydrocarbonates.
1. Fats and oils.

Butyrin,	Olein,	Caprinin,
Caprolin,	Palmitin,	Myristin,
Caprylin,	Stearin,	Cholesterin.

2. Fatty acids.

Oleic acid,	Capric acid,	Lactic acid,
Stearic acid,	Formic acid,	Leucic acid,
Palmitic acid,	Acetic acid,	Oxalic acid,
Butyric acid,	Propionic acid,	Benzoic acid,
Caproic acid,	Sebacic acid,	Carbolic acid.

(B) *Nitrogenous.*

(*a*) Albuminous substances.
1. The true albumins.
   Egg-albumin.
   Serum-albumin.
2. Derived albumins.
   Acid-albumins.
   Syntonin.
   Alkali-albumins.
   Casein.

3. Globulins.
    Globulin of crystalline lens.
    Serum-globulin.
    Fibrinogen.
    Myosin.
4. Peptones and albuminoses.

(*b*) Albuminoid substances.
    Callogen.
    Elastin.
    Keratin.
    Mucin.
    Protonuclein.
    Hæmoglobin.

(*c*) Ferments.
1. Unorganized ferments.
    Amylopsin.
    Ptyalin.
    Pepsin.
    Trypsin.
    Steapsin.
    Invertin.
    Milk-curdling ferment.
    Fibrin-ferment.
2. Organized ferments.
    Bacteria.
    Bacterium lactis.
    Saccharomyces.
    Putrefactive bacteria.
    Pathogenic bacteria.

(*d*) The coloring matters.
    Hæmoglobin.
    Bile-coloring matters.
    Urine-coloring matters.
    Melanin.

(*e*) Decomposition products.

Leucin.
Tyrosin.
Glycin.
Kreatin and kreatinin.
Xanthin and hypoxanthin.
Uric acid.
Hippuric acid.
Urea.
Indol and skatol.
Lecithin, protagon, neurin, and cerebrin.

QUESTIONS AND ANSWERS.

SUBJECT.—*The Proximate Principles.*
Lectures IX.–X. inclusive.

146. Name the chemical elements which enter into the chemical composition of the animal body.

147. Which of these exist in the body in a free state?

148. What is a proximate principle?

149. Name the inorganic ingredients of the animal body.

150. What is the proportion of water in the animal body?

151. What percentage of water is contained in blood, bone, enamel?

152. Enumerate the inorganic salts in the animal body.

153. What are the uses of the chlorides in the body?

154. Where are the sulphates principally found?

155. Where are the phosphates, the carbonates, and the calcium salts principally found?

156. Name the inorganic acid existing as such in the human body. State where found.

157. Name the gases existing as such in the animal body. State where they are found.

158. Name the metals existing in the animal body. State where they exist.

159. Where do the animal inorganic ingredients originate, how are they taken into the body, and how are they eliminated?

160. Give a short classification of the organic ingredients of the animal body.

161. How do the organic ingredients of the animal body originate, and where?

162. What do you understand by carbohydrate substances?

163. Name the carbohydrate substances existing in the human body. State where they exist.

164. Give chemical tests for starch, dextrin, glucose.

165. What do you understand by hydrocarbonate substances?

166. Mention the hydrocarbonate substances existing in the animal body.

167. In what form are the carbohydrates and hydrocarbonates eliminated from the body?

168. What do you understand by organic nitrogenous substances?

169. What substances of our body belong to this class?

170. Which are the albuminous substances in the animal body?

171. Give the general properties of the albuminous substances.

172. Mention and describe the tests used for the albuminous substances.

173. Name the native albumins, the derived albumins, and the globulins.

174. What are the peptones, and what are propeptones or albuminoses?

175. What are the albuminoid substances? Enumerate them.

176. What is a ferment?

177. Which are the unorganized ferments or enzymes existing in the human body? State where they are found.

178. What is a hydrolytic, a proteolytic, and an amylolytic ferment?

179. Name some of the organized ferments found in the animal body.

180. Name the coloring matters of the tissues and fluids of the animal body. To what class of substances do they belong?

181. Name some of the principal products which are found in the animal body as the result of the decomposition and splitting-up of the albuminous and albuminoid substances of the body.

182. To what class of substances do the decomposition products of the albuminous and albuminoid substances belong?

183. What is urea? Where is it found in the animal body?

184. How are the organic nitrogenized substances found in the plants?

185. What is the ultimate product of the decomposition of the albuminous and albuminoid substances in the animal body?

LECTURE XI.

NUTRITION.

Food.

The constant physiological activity of the tissues and organs of the animal body is accompanied by a constant destruction and formation of the substances composing the tissues and organs of the body. This constant formation and destruction of substances in the animal body is called the metabolism of the tissues. It consists of two distinct phases—namely, (*a*) the destructive metabolism, katabolism, or dissimilation, and (*b*) the constructive metabolism, anabolism, or assimilation. The metabolic processes consist of a series of chemical changes, and result in the production of the forces, motion and heat. The katabolic changes result in the production of substances which, as effete products, are eliminated from the body with the excretions.

The anabolic changes necessitate the introduction of materials from which the tissue substances are formed. These nutritive materials are introduced into the body with the food.

The nutritive materials required by the animal body may be enumerated as follows: *inorganic substances*—viz., water and salts; *organic substances*—viz., carbohydrates, fats, and albuminous substances.

The food, in order to maintain the nutritive functions in the body, must contain all these substances in proper quantity and quality, and the organism suffers seriously if deprived, for any length of time, of one or the other nutritive materials mentioned.

Herbivora are those animals which derive their organic food from vegetables and plants only, and their organism is capable of transforming the organic material so obtained into material for its own tissue. *Carnivora* are those which derive their organic food from the animal kingdom only. *Omnivora*—to which man belongs—take their organic food from the animal and vegetable kingdoms.

We select for our food articles which contain the materials required for the nutrition of our organism.

1. *Inorganic substances, water and salts.* These are partly taken as such, partly with other articles of food of which they are ingredients.

2. *Organic substances.* (*a*) Vegetable—cereals, such as wheat, rye, oats, barley, rice, etc.; leguminous fruits, such as peas, beans, lentils, etc.; potatoes, vegetables and salads, fruits; stimulants—coffee and tea, alcoholic stimulants, spices. (*b*) Animal—meats, milk, eggs.

Food in order to be nutritious must be pure; it must contain in proper quantity and quality all the materials required by the organism; it must be properly prepared and palatable, and it must be adapted to the climate, to the work the individual performs, and to the age of the individual.

In the following I will describe briefly the articles chosen by man for food:

Water constitutes about 58.5 per cent of the whole body, and the great importance of a constant exchange is clear when we take into consideration the many important uses of water in the body. The average quantity of water required by the healthy adult is 2,500 to 2,800 cubic centimetres in twenty-four hours. Rain-water and that of wells, springs, rivers, and streams is used for drinking purposes. Rain-water which is collected in reservoirs and in cisterns is the purest. The water of wells, and especially that of springs, generally contains various mineral ingredients, a small quantity of oxygen, and a larger quan-

tity of carbon dioxide. The water of running waters—rivers, streams, etc.—is the most impure, and requires purification by filtration, etc., before it can be used for drinking purposes.

Good drinking-water must be *pure*, *clear*, *colorless*, *odorless*, and *tasteless*.

The more common *impurities* of water are:

(*a*) The salts of calcium and magnesium with CO_2.

(*b*) Sulphuric acid and sulphates.

(*c*) Chlorine and chlorides.

(*d*) Nitrates and nitrites.

(*e*) Sulphuretted hydrogen.

(*f*) Ammoniates.

(*g*) Organic ingredients and bacteria.

The salts of calcium and magnesium with CO_2 render water hard, and, when too abundant, make it unfit for drinking. The relative hardness of water is determined by the time required to produce foam when soap is shaken with the water; it generally takes longer with hard water. The hardness of drinking water must not exceed twenty degrees; one degree of hardness means 1 part of the salts of calcium and magnesium with CO_2 to 100,000 parts of water. The hardness of water can be reduced to some extent by boiling. The various other inorganic impurities can often be recognized by the taste and odor when they are contained in the water to such an extent as to make it unfit for drinking purposes.

One of the greatest qualifications of good drinking-water is that it *does not contain* any organic ingredients. Stagnant waters, and waters in the vicinity of privies, stables, dunghills, cemeteries, etc., are often contaminated by organic impurities. Their presence is determined by the presence of nitrogen or nitric acid; and also by the recognition, under the microscope, of many micro-organisms which develop in such water. It has been found that diseases such as typhoid fever, dysentery, malarial fever,

etc., are caused by drinking impure water contaminated with organic impurities ; and for this reason, in localities where contamination with organic impurities is possible, the water should be well boiled before use.

The *inorganic salts* which constitute a part of our organism are taken in as such with the various articles of food. When the system is deprived of these there results an insufficient nutrition of the tissues of which they constitute a part.

2. *The organic food substances:* (*a*) The *cereal fruits*—wheat, rye, corn, and rice—are the most important of the vegetable kingdom.

According to *J. Koenig*, the chemical composition of these cereals is as follows:

	Water.	Albumen material.	Starch.	Sugar.	Dextrin.	Fat.	Cellulose.	Ash.
Wheat...	.13.56	12.42	64.07	1.44	2.38	1.70	2.66	1.79
Rye........	15.26	11.43	62.00	0.95	4.88	1.71	2.00	1.77
Corn.......	13.88	10.05	58.96	4.59	3.23	4.76	2.84	1.69
Rice.......	14.41	6.94	$\underbrace{\qquad\qquad\qquad}_{77.61}$			0.51	0.08	0.45

From this table it will be seen that these cereal fruits contain : 1, water ; 2, albuminous material; 3, starch; 4, sugar; 5, dextrin; 6, fat; 7, cellulose; 8, salts. The latter are principally the salts of magnesium, calcium, and phosphorus; chlorides and salts of sodium are but sparingly present, and it is therefore necessary that such salts—*i.e.*, sodium chloride—be added in the preparation of these cereals. The grains of the cereals are ground to flour, and this is principally used in the preparation of bread. The table also shows that wheat contains the greatest percentage of albuminous matter in these cereals, and it is therefore the most nutritious. Barley, oats, etc., are not easily digested, on account of the great quantity of cellulose they contain.

The *leguminous fruits* used as food articles are: beans, peas, lentils, etc. They contain from 22 to 24 per cent of albuminous material, 50 to 54 per cent of carbohydrates, and

4 to 8 per cent of cellulose. On account of the large percentage of the albuminous material *legumin*, they are valuable and nutritious foods.

Potatoes contain 76 per cent of water, 20 per cent of starch, about 1.70 per cent of albuminous material, and 0.97 per cent of inorganic salts.

Vegetables are the roots and leaves of many plants, and contain starchy material, sugar, inorganic salts, and organic acids. The salts and organic acids render these valuable articles of food.

Fruits contain sugar, dextrose, starch, and acids such as citric, tartaric, acetic, and oxalic; the latter principally stimulates the appetite.

Stimulants. (*a*) Alcoholic stimulants, such as wines, beers, whiskeys, brandies; (*b*) coffee, tea, cocoa, and chocolate; (*c*) spices. These substances are principally taken to stimulate the secretion of the digestive juices.

(*b*) *The animal food articles. Meat* constitutes the principal article of animal food. It contains *myosin* of the muscle-tissues, *serum-albumin* of the juice, *gelatin* of the connective tissues, *elastin* of the elastic tissues, and, besides these, *hæmoglobin*, *fatty matter*, *salts*, and *water*.

The meats generally used are the flesh of the ox—beef and veal; that of the sheep—lamb and mutton; and that of the pig—pork, bacon, and ham. Of these beef contains the largest amount of albuminous matter—about 20 per cent—and is therefore the most nutritious. Veal and lamb are less digestible than the other meats. Pork contains only about 10 per cent of albuminous matter, but about 48 per cent of fat; it is therefore not easily digested and least nutritious. Poultry, venison, and fish, and many animals living in water, such as oysters, lobsters, etc., must also be considered as meats. Poultry is very nutritious; it contains about 21 per cent of albuminous matter.

Letheby gives the composition of the food articles of this class as follows:

	Water.	Albumen.	Fats.	Salts.
Beef	.72	19.3	3.6	5.1
Veal	.63	16.5	15.8	4.7
Mutton	.72	18.3	4.9	4.8
Pork	.39	9.8	48.9	2 3
Poultry	.74	21.0	3.8	1.2
Whitefish	.78	18.1	2.9	1.0
Oysters	.75	11.72	2.42	2.73

The percentages given are those of lean meat. These meats when fat contain a greater proportion of fat and a smaller proportion of water and albuminous material.

The meats are prepared for eating by cooking; this produces certain changes in the meats which increase their digestibility.

The boiling of meat causes the extraction of the soluble albuminous materials, the fats, salts, etc., which, dissolved in the water, constitute the meat-extract. The albuminous matters coagulate and form a grayish foam, which floats on the surface of the water. The meat-extract or broth thus prepared contains, therefore, no albuminous matter. The meat so boiled contains the myosin. which is coagulated, and it is for this reason not very digestible. Together with fat, salts, and spices it is still a nutritious food.

Fried meats are more digestible and have a greater nutritive value than boiled. The reason for this is that during the process of frying the albuminous materials on the surface are only firmly coagulated, and the other materials are not extracted to such a degree.

Meat-extracts are prepared by extracting the soluble materials of meat with cold water; from the extract so obtained the gelatin, albumen, and fat are removed.

Other methods of preparing meats are smoking, pickling, drying, and canning; these serve to preserve the meat.

Raw meat is not easily digested; it must, therefore, be scraped very fine if it is to be eaten in a raw condition. The meat of the pig should never be eaten raw, on account of the occasional appearance of the *trichina spiralis* and

of the organism from which the tapeworm (*tænia solium*) develops. Great care should be taken to avoid eating meats in a state of decomposition, as in them are often found substances which are deleterious to the health.

Milk is the secretion of the mammary glands of the female. The mammary glands are compound acinous glands; their cells possess the property of transforming blood constituents into those of the milk.

Milk is composed of water, casein, albumen, fat, sugar, and salts, principally chlorides and phosphates. This composition of the milk makes it a valuable food article. Cow's milk is generally used by adults; also the milk of goats and asses. To the feeding of infants mother's milk is best adapted, because it is rich in milk-sugar and contains more albumen than casein, which causes it to coagulate in the infant's stomach in fine flocks. Ass's milk, in its composition, resembles mother's milk, and is for this reason often used as a substitute. Cow's milk contains more casein than albumen; it consequently coagulates in the stomach in large, hard, indigestible masses. It also contains a smaller percentage of sugar than mother's milk, and for these reasons must be diluted and an addition of sugar made in order to be serviceable as a substitute for mother's milk. Goat's milk contains a still larger quantity of casein than cow's milk. The main objection to the use of animal milk as a substitute for mother's milk in the feeding of infants is the fact that in the former microorganisms are often developed which are deleterious to the health of the infant and which make it necessary to sterilize or pasteurize it before use.

Butter and *cheese* are made from milk. Another preparation of milk is an alcoholic drink called *kumyss*. It is made by the fermentation of the milk-sugar, which produces alcohol.

J. Koenig gives the following quantitative composition of milk:

	Water.	Casein.	Albumen.	Fat.	Sugar.	Salts.
Mother's milk....	87.09	0.63	1.31	3.90	6.04	0.49
Cow's "	87.41	3.01	0.75	3.66	4.82	0.70
Goat's "	85.91	2.87	1.19	4.09	4.45	0.66
Ass's "	90.04	0.60	1.55	1.39	6.25	0.31

Milk is a slightly alkaline, white fluid. It does not coagulate when heated. On standing it sours, due to the decomposition of the milk-sugar and the production of lactic acid. This is due to the bacterium lactis, the germs of which are contained in the air. In sour milk the casein is coagulated.

Eggs, principally those of birds, are very valuable as food. They contain in proper proportions all materials essential for the nutrition of the body.

An egg is composed of a white and a yolk. The white of egg contains water 85 per cent, albuminous matter 12½ per cent, fat 0.25 per cent, and salts 0.59 per cent, principally chlorides of sodium and potassium. The yolk of the egg contains water 50.8 per cent, albuminous material 16.25 per cent, fat 31.75 per cent, and salts 1 per cent, principally salts of phosphorus and lime. Of the two the yolk contains the more nutritious material and is more easily digested. Eggs when soft-boiled are most digestible, because the albuminous material of the egg is coagulated in fine flocks.

From this description of the various food articles we learn that most of them contain in proper proportions the essential ingredients of food—namely, water, inorganic salts, albuminous material, carbohydrates, and fats.

The absolute quantity of these essential food constituents which an individual requires depends upon the age, sex, occupation, and climatic conditions.

It may be said that, in order to maintain the equilibrium of nutrition in the body, the elementary composition of the nutritive material taken must be equal to the elementary composition of the effete products eliminated from the body.

When the elaboration of more heat in the body is required, as is the case in cold weather, and when great muscular work is done by the individual, then the dissimilation of the tissue substances is increased and necessitates the taking of more nutritious material.

During the growth and development of the individual the nutritious material taken should be greater than the effete material. In old age the materials excreted generally exceed in their elementary composition that of the nutritive materials taken.

The want of nutritive material is indicated by hunger and thirst. An insufficient supply of nutritive materials is indicated by loss of weight. The loss which the tissues suffer during the inanition varies in the different organs. Adipose tissue and muscles lose first and most. Starvation is indicated by loss of weight and decrease of nitrogenous effete products.

In man death from starvation occurs in about three weeks ; in the last stages there is a general debility, decreased temperature, and coma.

The average quantity of the various food materials daily required by an adult has been estimated to be: water, 2,500 to 2,800 grammes ; inorganic salts, 32 grammes ; albuminous substances, 130 grammes ; fats, 84 grammes ; carbohydrate material, 400 grammes ; oxygen (inhaled with the air), 744 grammes.

From this table it may be seen that food should contain organic nitrogenized and organic non-nitrogenized materials in a proportion of 1 to 4 or 1½ to 4½.

The inorganic food materials are taken in as such with the food and drink, and they are eliminated as such with the excreta.

The organic food materials are composed of the following elementary constituents : carbon, nitrogen, hydrogen, oxygen, phosphorus, sulphur, and iron. These materials are assimilated into tissue substances and undergo changes;

they are finally excreted as urea, carbon dioxide, and water, which contain the same elementary substances.

The nutritive values of the various food materials differ. The albuminous substances must be considered as the most important. The animal cell is capable of reproducing its own living material from albuminous material only, for which no other nitrogenized substance, such as albuminoid, gelatin or gluten, etc., can be substituted. If the cell is deprived of a supply of albuminous material it dies.

Albuminous materials contain all the elements required for the tissue-formation in the body. Experiments have been made to determine whether animals cannot be sustained by feeding them with albuminous material and inorganic foods alone. It has been demonstrated that for a short time this can be done, because albuminous material is transformed in the body into the living matter of the cells and also into carbohydrates and fat. The experiments could not be continued for a long time, because the animals required such enormous quantities of albuminous material in order to renew the quantity of carbon and hydrogen which is constantly eliminated from the body with the carbon dioxide and water. The quantities of albuminous materials required to do this are so great that the animal organism is incapable of elaborating them.

Carbohydrates and fat cannot alone support life, because they do not contain nitrogen. They are principally calorifacious foods, owing to the rapid combustion of the carbon and hydrogen they contain.

The nutritive value of the inorganic ingredients of the food is explained by their many uses and wide distribution as tissue constituents.

Before finishing this subject I will describe the effects of over-feeding.

I have before stated that albuminous material contains all the necessary elementary constituents of life, whereas fat and carbohydrates alone cannot support life. The ani-

mal digestive apparatus is capable of digesting a greater quantity of food than is required to maintain an equilibrium of nutrition.

An over-feeding with albuminous materials generally results in an increased excretion of the products of the dissimilative process of the tissues. Only a small quantity of the plus of albuminous material is transformed into tissue-substance, resulting in an increase of flesh.

An over-feeding with fat and carbohydrate material results in an increase of fat-tissue, if the quantity of albuminous material given with the fat and carbohydrate food is that quantity which would be required to maintain the nutritive equilibrium without the addition of any fat or carbohydrate material.

The result of an excessive tissue-formation is *obesity;* this is not necessarily an increase of fat-tissue only, but often an increase of flesh. The condition is generally the result of an excessive taking of nutritive materials, but often it is also due to an abnormal condition of the metabolic processes in the body, as is the case, for instance, in hereditary obesity.

The conditions favoring obesity are as follows: *a*) Taking of large quantities of albuminous substances and fat or carbohydrate material. If the quantity of albuminous material is decreased, an increase of fat or carbohydrate material is necessary; in such a case no increased formation of fat will take place in the body. Carbohydrate material is transformed to a certain extent into fat.

(*b*) A decrease of the katabolic processes in the body, as takes place when the muscular and mental activity is decreased.

(*c*) Conditions decreasing the red blood-corpuscles, they being the oxygen-carriers, result in the decrease in the supply of oxygen and in the processes of oxidation in the body.

(*d*) The imbibing of alcohol, which, being rapidly oxidized in the body, prevents a rapid oxidation of fat.

(*e*) Phlegmatic temperament, small mental activity, also favor an excessive development of flesh and fat, whereas excitement, great mental work, strain, worry, etc., are conditions opposing obesity.

People suffering from obesity should observe the following rules:

(*a*) The gradual reduction of all nutritious material.

(*b*) The increase of muscular activity.

(*c*) Increase in the elimination of heat from the body by cool baths.

(*d*) The increase and stimulation of the circulation by friction and massage. Care should be taken to avoid a partial reduction or a total abstinence from any one class of nutritious materials. The amount of fat and carbohydrate foods should be reduced first. This necessitates a slight increase of albuminous foods.

In dieting for obesity no liquids should be taken with the food, as they retard absorption and digestion.

Another frequent result of over-feeding is indigestion, caused by a decomposition of food in the alimentary canal, resulting in the formation of the products of putrefaction.

Gout is considered the result of over-feeding with albuminous materials; they are mainly elaborated in the liver, but as this organ is unable to elaborate a great excess of albuminous material, the incomplete oxidation of the materials causes the pathological condition known as gout.

The quantity and quality of food materials required at the different ages depend upon the condition of the digestive organs and juices, and I will speak of this more in detail in a later lecture.

QUESTIONS AND EXERCISES.

SUBJECT.—*Food.*

Lecture XI.

186. What do you understand by metabolism, anabolism, katabolism, assimilation, dissimilation?

187. What are the effects of the metabolism of the tissues?

188. What is meant by food?

189. Name the essential nutritive materials.

190. What do you understand by herbivora, carnivora, omnivora?

191. What is the quantity of water required by an adult in twenty-four hours?

192. What uses does water serve in the animal organism?

193. What are the sources of drinking-water?

194. Name some impurities of water.

195. What should be the properties of good drinking-water?

196. What produces hardness of water?

197. What is meant by a degree of hardness?

198. What maximum degree of hardness may potable water have?

199. What effect has boiling on water?

200. Name some vegetable articles chosen by man as food.

201. Which of the cereals has the greatest amount of albuminous substance?

202. Name the principal leguminous fruits chosen by man as food.

203. Give the composition of potatoes.

204. Explain the nutritive value of the stimulating foods.

205. Name the principal meats used as food.

206. Which of the meats has the most nutritive value?

207. Why should not meats be eaten in a raw condition?

208. What is the effect of boiling or frying meats?

209. Why is fried meat more nutritious and more easily digested than boiled meat?

210. Which of the meats contain the greatest percentage of albuminous material?

211. Where is milk formed?

212. Give the composition of cow's milk, mother's milk, goat's milk, and ass's milk ?

213. Why is mother's milk most preferable for feeding infants ?

214. How should cow's milk be prepared in order to serve as a substitute for mother's milk ?

215. Give food articles prepared from milk.

216. Give the composition of the white and the yolk of the egg.

217. Name the elements contained in the various nutritious articles.

218. What is the quantity of albuminous material required by an average adult in twenty-four hours ?

219. Can any other nitrogenous materials be substituted for the albuminous substances ? Explain in detail.

220. What is the quantity of fat and of carbohydrate material required by an average adult in twenty-four hours ?

221. Can the life of an animal be sustained when it is fed only with non-nitrogenous organic materials ? Explain.

222. What is the quantity of inorganic salts required by an average adult in twenty-four hours ?

223. What is meant by the equilibrium of nutrition ?

224. What conditions make an increase in the supply of nutritive materials necessary, and why ?

225. What would be the result of an insufficient supply of nutritive materials ?

226. Which structures of the body suffer most as a result of starvation ?

227. What should be the relation of the albuminous material and the organic non-nitrogenous materials (fat, starches, sugars) in a mixed diet ?

228. In what form are the elementary constituents of the organic nutritious materials taken in and eliminated from the body ?

229. Compare the nutritive value of albuminous substances with that of fats and carbohydrates.

230. Name the qualities which food should have in order to be good and nutritious.

231. Name three kinds of food from which starch is derived, and give the percentage of starch in each.

232. Name diseases produced by drinking impure water.

233. Show the value of eggs as an article of food.

234. Name some of the impurities found in rain-water that is stored in cisterns.

235. Name four inorganic substances that should be present in our food, and

236. State why each is important.

237. What danger often exists in water used for drinking, and how can such danger be averted?

238. Are inorganic ingredients of food necessary to sustain life? Why?

239. Are albuminous matters solid or fluid? Where are they found in the body?

240. What advantage is derived from a mixed diet?

241. Mention the non-nitrogenous constituents of food and the nutritive value of each.

242. Name eight principal carbohydrates used for food.

243. What effect does an excessive starch diet produce?

244. What is the composition of human milk?

245. What kind of foods would you recommend in cases of obesity?

246. What are amyloid foods? Albuminous foods? Give three examples of each.

247. Describe the physiological causes of obesity.

248. Discuss the effect of cooking food as a means of rendering it more digestible.

249. What is the daily quantity of food required to nourish the human system?

250. Mention the essential elements of foods. Give the relative food-value and ease of digestion of the meats.

251. What diet should be prescribed to reduce obesity?

LECTURE XII.

DIGESTION.

By the word *digestion* we mean a series of chemical and physical processes by which the articles of food, while in the alimentary canal, are rendered absorbable.

The chemical processes of digestion include the action of the various digestive juices upon the foods. The physical or mechanical processes include the chewing and swallowing of the food and the peristaltic movements of the stomach and intestines, which have for their purpose the thorough mixing of the food with the digestive juices and the conveying of it onward in the alimentary canal.

The digestive apparatus consists of the alimentary canal and a number of accessory organs—viz., the salivary glands, the liver, and the pancreas.

The *alimentary canal* begins at the mouth and ends at the anus. It is lined throughout its whole length with mucous membrane, and has opening into it the numerous glands which secrete the digestive juices.

The alimentary canal is divided into various portions, which, in their order, are as follows: mouth, buccal cavity, pharynx, œsophagus, stomach, small intestines, and large intestines.

In man the alimentary canal is about six times the length of the whole body.

The *digestive juices* are the saliva, gastric juice, pancreatic juice, intestinal juice, and bile.

The process of digestion consists of seven stages—viz. :

1. Prehension.
2. Mastication.

3. Insalivation.
4. Deglutition.
5. Stomach digestion.
6. Intestinal digestion.
7. Defecation.

I will describe the several stages, together with the anatomy and structure of the various portions of the digestive apparatus, and the composition, action, and mode of secretion of the various digestive juices.

1. *Prehension.*

The act by which the food is introduced into the buccal cavity is called prehension. Man uses his hands and lips for this purpose.

The *buccal cavity* is the upper portion of the alimentary canal, into which the food is introduced through the anterior orifice, the mouth. The buccal cavity is oblong and arched. Its boundaries are as follows: In front, the lips, the alveolar processes of the jaws, and the teeth contained therein; behind, it is continuous with the pharynx through the fauces; laterally it is enclosed by the cheeks, by the alveolar processes of the jaws, and by the teeth; the roof is arched, and is formed by the hard palate in front and the soft palate behind. The floor is formed of soft parts, which, from within outward, may be enumerated as follows: mucous membrane, submucous tissue, supporting glands and vessels, muscles—viz., the mylo-hyoid and the genio hyoid—subcutaneous tissue, and skin. The tongue also forms part of the floor of the buccal cavity.

Opening into the cavity are numerous glands—viz., the salivary glands and the mucous follicles. The whole buccal cavity is lined with mucous membrane, which is covered with flat, stratified epithelium. In the mouth the food is masticated and insalivated.

2. *Mastication.*

The act of chewing or masticating has for its purpose the division of the solid parts of food into small particles,

so that these may be more easily permeated and attacked by the digestive juices. From this it is clear that a proper mastication of the food is essential for its digestion, and a proper mastication is possible only when the principal organs of mastication—*i.e.*, the teeth—are in proper order. The teeth in the various classes of animals are shaped and arranged in a manner most suitable for the mastication of the food taken by them. The herbivora have teeth with large, flat, corrugated grinding surfaces. The carnivora have teeth with cutting edges; these have points or cusps for the tearing of flesh. The omnivora, to which man belongs, have both the teeth of the carnivora and the herbivora.

The complete number of teeth in the human adult is 32—namely, 16 in each jaw. The 8 teeth contained in each lateral half of each jaw are called, beginning with the anterior, 1 central incisor, 1 lateral incisor, 1 canine, 2 bicuspids, 2 molars, and 1 wisdom tooth.

Mastication is effected by an up-and-down, and lateral or grinding, motion of the lower jaw, by which the teeth are brought against those of the upper jaw, and the food, which by the motion of the lips, cheeks, and tongue is brought between the teeth, is cut, torn, and ground until it is well divided and subdivided. During mastication the food becomes thoroughly mixed with the saliva and forms a soft, slippery mass—the *bolus.*

The movements of the lower jaw are effected by the *muscles of mastication,* which may be classified as follows:

(*a*) *The muscles raising the lower jaw:*

The temporal muscles,
" masseter,
" internal pterygoid.

(*b*) *The muscles depressing the lower jaw:*

The genio-hyoid muscles,
" mylo-hyoid "
" platysma myoides,
" anterior portion of the digastric.

(*c*) *The muscles producing the grinding motion :* The external pterygoid muscles. They bring the jaw forward, and by their alternate contraction produce the lateral or grinding motion.

The act of mastication is a voluntary, but also an involuntary nervous act.

The centre of mastication is located in the medulla oblongata.

The sensory nerves are branches from the fifth and the tenth cranial nerves : by these the stimulus—viz., the presence of solid food in the buccal cavity—is conveyed to the centre.

The motor branches supplying the muscles of mastication are from the fifth, seventh, and twelfth cranial nerves. Their distribution is as follows: The muscles raising the lower jaw are supplied by branches from the inferior maxillary division of the fifth cranial nerve; the muscles depressing the lower jaw—*i.e.*, the mylo-hyoid and anterior portion of the digastric—by branches from the fifth; the genio-hyoid, by a branch from the twelfth; and the platysma myoides, by a branch from the seventh cranial nerve.

The pterygoid muscles receive motor branches from the fifth cranial nerve through its inferior maxillary division.

The Structure and Development of the Teeth.—The teeth are contained in the alveolar processes of the jaws. A tooth consists of a *crown*—viz., the part projecting above the gums—and one or more *roots*, which are contained in the alveoli; the constricted portion between crown and roots is called the *neck*. The structures composing a tooth are the pulp, the dentin, the enamel, and the cementum.

The *pulp* is composed of myxomatous tissue—viz., of nerve filaments, blood-vessels, and delicate fibrillar tissue supporting these. The external surface of the pulp is covered with a single layer of branched cells, resembling epithelial cells; they are called the *odontoblasts*. The pulp is

contained in the pulp-chamber, a cavity in the interior of the tooth. The structures composing the pulp enter by a foramen at the apex of each root, called the *apical foramen*, or *foramen dentium*.

The *dentin* is developed from the odontoblasts; it forms the *matrix* or body of the tooth: it consists of 27.70 per cent of organic matter and 72.30 per cent of inorganic matter—viz., calcium and magnesium phosphate and carbonate, and traces of iron and fluorine.

Examined under the microscope, dentin is seen to be pierced by numerous canaliculi, which, in a wavy course, radiate from the pulp-chamber toward the periphery; in their course these canaliculi frequently anastomose. The *dentinal canaliculi*, as they are called, are lined by a delicate membrane called the *dentinal sheath*. The canaliculi contain the delicate processes of the odontoblasts covering the pulp; these processes are called the *dentinal fibres;* they terminate in the *interglobular spaces*, which are shallow excavations in the outer surface of the dentin, between this and the enamel.

The *enamel* is the tissue which covers the crown. It contains about 3 per cent of organic and 96 to 97 per cent of inorganic matter, principally calcium phosphate, carbonate, and fluoride, and magnesium phosphate.

Enamel consists of flattened, hexagonal *prisms*. They are about $\frac{1}{5000}$ of an inch thick.

The *cementum*, or *crusta petrosa*, has the structure of bone-tissue. It covers the roots of the teeth in a thin layer. The cementum is covered with a delicate vascular membrane called the *pericementum* or *periodontal membrane*. This also forms the periosteum of the alveolus, and is continuous with the periosteum covering the alveolar process.

The crown of a tooth is covered with a thin, structureless membrane called the *cuticula* or *Nasmyth's membrane*. It is only present a short time and soon wears off.

The *gums* are the structures covering the alveolar processes. They consist of a mucous membrane devoid of mucous follicles.

The *development of the teeth* begins at about the end of the second month of fœtal life. At about this time there develops upon the gum covering the jaws a thick, elevated ridge which is composed of multiple layers of epithelial cells. At the same time a long depression or furrow develops in the gum along the under portion of the ridge. This groove or furrow is called the *dental groove.* This gradually deepens into the gum-tissue and becomes widened in its deeper portion. The dental groove gradually becomes filled with elongated epithelial cells, and these form in the groove a mass which is called the *enamel-organ.* During the formation of this a conical papilla is developed from the cells of the mucous membrane of the gum—namely, from the floor of the dentinal groove. The papilla, also called the *dentin-germ*, grows, and its apex is covered by the *enamel-organ.* At about this time the outer cells of these structures develop into connective tissue, which forms a sac called the *tooth-sac*, and enclosed in it are the enamel-organ and the papilla.

The enamel-organ at this time consists of layers of cells, which are compressed by the papilla. The cells lying next to the papilla become calcified and develop into the hexagonal, flat enamel prisms, which therefore are calcified epithelial cells. Those cells of the enamel-organ which lie toward the tooth-sac become horny and form the cuticula which in early life covers the enamel.

The dentin is developed from the outer layers of the cells of the papilla—viz., the odontoblasts. The remainder of the papilla constitutes the pulp of the tooth.

The cementum is developed from the lower portion of the dentinal sac by a process of ossification.

The human being is provided with two sets of teeth, called respectively the temporary and the permanent.

The *temporary* set consists of 20 teeth, 10 in each jaw. They are enumerated from the front as follows: 2 central incisors, 2 lateral incisors, 2 canines, 2 first molars, 2 second molars. The formation of the *temporary, deciduous* or *milk teeth,* as they are called, begins at about the seventh month and is completed by the twenty-fourth or thirtieth month.

The *periods of the eruption of the temporary teeth* are as follows: at about the seventh month, the central incisors; at about the seventh to tenth month, the lateral incisors; at about the twelfth to fourteenth month, the first molars; at about the fourteenth to twentieth month, the canines; at about the eighteenth to twenty-fourth month, the second molars. The second molars often appear as late as the third year. The upper teeth generally precede those of the lower jaw.

The *development of the temporary teeth* begins at about the following periods: seventh week, the first molars; eighth week, the canines; ninth week, the incisors; tenth week, the second molars.

The permanent set consists of 32 teeth, 16 in each jaw. They are enumerated from the front as follows : 2 central incisors, 2 lateral incisors, 2 canines, 4 bicuspids, 6 molars. The eruption of the permanent teeth begins at about the sixth year and is completed by the twenty-first to the twenty-fifth year.

The *periods of the eruption of the permanent teeth* are as follows : at the sixth year, the first molars ; at the seventh year, the central incisors ; at the eighth year, the lateral incisors ; at the ninth year, the first bicuspids ; at the tenth year, the second bicuspids ; at the eleventh to twelfth year, the canines ; at the twelfth to thirteenth year, the second molars ; at the seventeenth to twenty-fifth year, the third molars or wisdom teeth.

The *development of the permanent teeth* begins before the development of the temporary set is completed.

The permanent set consists of those teeth which succeed the 20 temporary teeth.

The permanent teeth succeeding the temporary set are the incisors, the canines, and the bicuspids which take the place of the molars of the temporary set.

The development of these 20 teeth begins before the ridges of the dentinal groove become obliterated. At about this time there appears an indentation or depression at the inner wall of the neck of the tooth-sacs of the temporary teeth. These indentations result in the formation of a *secondary dental ridge* and *dental groove* or *furrow*, and in this there develop the enamel-organs and papillæ for the permanent teeth; these structures also become surrounded by a tooth-sac. These permanent teeth develop near the inner wall of the alveolar portion of the temporary teeth.

The *superadded permanent teeth*—namely, the three molars in each lateral half of the jaw—develop successively from the tooth in front. The manner of their development is about as follows: From the enamel-organ of the second temporary molar a backward extension forms, which becomes separated, and from which, at about the fourth month after birth, the enamel-organ for the first permanent molar develops; from this, at about the seventh month, the enamel-organ for the second molar, and from this again, at about the third year, the enamel-organ for the third molar, are developed in a similar manner. The papillæ and other structures of the permanent teeth develop like those of the temporary teeth.

The eruption of the teeth begins when calcification is sufficiently completed to stand the pressure which causes their eruption.

The *alveoli* are formed by an ossification of the fibrous septa between the developing teeth. Fibrous septa, which afterward ossify, are situated between the developing tem-

porary and permanent teeth, and also between those already formed.

The developing permanent teeth press against these septa, causing their absorption. Finally the alveolar portion of the temporary teeth becomes eroded and absorbed as a result of the pressure of the developing permanent teeth. During this period numerous multinuclear cells, resembling leucocytes, are developed near the alveolar portion of the temporary teeth. They are called *odontoclasts,* and are believed to play an important rôle in the absorption or carrying-off of the particles of inorganic material from the osseous septa and the alveolar portion of the temporary teeth. These become loosened through this process, and are finally shed to make room for the permanent teeth.

The importance of the teeth as essential organs of digestion is well known to the physician and the dental surgeon, but perhaps not sufficiently recognized and understood by people in general. It is a frequent occurrence that improper mastication of the solid foods is the cause of many ailments, such as digestive disorders, anæmia, debility, malnutrition, headaches, etc., all of which result from an insufficient digestion of the improperly masticated food. Improper mastication is sometimes a bad habit, but often it is caused by an improper condition or total absence of teeth. The teeth, like any other structures in the body, are subject to disease, malformation, and improper development. It is the aim of the dental surgeon to treat the diseased teeth and remedy any deficiencies by prostheses and other means; but, more than this, it is the duty and aim of the dental practitioner to treat conditions which lead to maldevelopment or irregularities of teeth, and to prevent the decay of the teeth by prophylactic measures. Caries is probably the most frequent disease of the teeth; it is principally due to bacteria, for the development of which the buccal cavity, if not kept constantly in a clean condition, presents a favorable field.

Drugs, especially acids and caustics, which are given as medicines, are often the causes of diseases of the teeth, and therefore care should be taken in their administration. They should either be given in capsules or, when liquid, taken through a glass tube.

LECTURE XIII.

DIGESTION (*continued*).

3. *Insalivation.*

By the term *insalivation* we understand the mixing of food with the secretions of the glands of the mouth.

The *glands of the mouth* are:

(*a*) The salivary glands—*i.e.*, 2 parotids, 2 sublingual, and 2 submaxillary.

(*b*) The mucous glands, situated in the mucous membrane of the cheeks and lips.

(*c*) The glands of the tongue.

The SALIVARY GLANDS are of the compound racemose or tubular racemose variety. They consist of a duct and a secreting portion; the latter consists of the tubular ramifications of the duct, and each of these terminates in a pouch-like expansion, the alveolus, which gives to the gland a lobular appearance.

The duct, the tubules, and the alveoli have one continuous basement membrane, which is lined with epithelial cells; in the secreting portion of the gland these are glandular; in the duct, flat or columnar cells.

The salivary glands are divided into three classes:

(*a*) The true salivary glands.

(*b*) The mucous salivary glands.

(*c*) The mixed or muco-salivary glands.

The true salivary glands. In this variety the alveoli are smaller than in the others; they are lined with nucleated glandular cells, which have an intranuclear network and a granular protoplasm; they secrete a watery fluid containing serum-albumin, and the alveoli are therefore called *serous alveoli.* The smaller tubules of these glands are

lined with pavement, the main duct with columnar, epithelium. The parotids are glands of this variety.

The *mucous salivary glands* secrete a ropy, viscid fluid which contains *mucin.*

The alveoli of the glands of this variety are called *mucous alveoli.* They are larger than those of the former variety, and they are lined by two kinds of epithelial cells, the *central* or mucous cells; they are nucleated, and have a fibrillar network and a transparent protoplasm called *mucigen,* which, during the activity of the cell, is converted into mucin. Scattered between these are the *marginal cells;* they are semi-lunar; their protoplasm is granular and contains no mucigen. The cells lining the alveoli of the glands of this variety do not completely fill the lumen of the alveoli. The smaller tubules are lined with granular cells, the ducts with large, cylindrical, nucleated epithelial cells which are finely striated toward the periphery and transparent toward the centre. The sublingual glands are of this variety. The *mixed* or *muco-salivary glands* have both serous and mucous alveoli. The human submaxillary glands are of this variety.

The *parotid glands* are the largest of the salivary glands. They are situated in front and below the external ear, beneath the skin and subcutaneous fascia. A parotid gland weighs from one-half to one ounce and has one duct, called *Steno's* or *Stenson's duct,* which is the size of an ordinary crow's quill and is about 2½ inches long; it opens on the inner surface of the cheek opposite the second molar of the upper jaw.

The *submaxillary glands* are situated in the anterior part of the submaxillary triangle, resting in a shallow depression on either side of the inner surface of the body of the lower jaw. A submaxillary gland weighs about two drachms and has one duct, called *Wharton's duct;* this is smaller than the duct of the parotid, being about 2 inches long, and opens on the side of the frenulum linguæ.

The *sublingual glands*, two in number, are situated beneath the mucous membrane of the floor of the mouth on either side of the frenulum linguæ. A sublingual gland weighs about one drachm, is almond-shaped, and has from ten to twenty fine ducts, called the *ducts of Rivini:* they open at the floor of the mouth. Some of these ducts also unite and form one duct, the *duct of Bartholin*, which opens into Wharton's duct.

The salivary glands are supplied with *lymphatics, blood-vessels*, and *nerves;* these structures enter and emerge at the hilus of the glands. The *blood-supply* of the salivary glands is as follows:

The parotids receive blood through branches from the external carotid arteries.

The submaxillary glands, through branches from the facial and lingual arteries.

The sublingual glands, through branches from the sublingual and submental arteries.

The *nerve-supply* to the salivary glands is as follows:

The parotids are supplied by branches from the carotid plexus of the sympathetic nerve, by branches from the seventh cranial or facial nerve, and by a branch from the auriculo temporal branch of the fifth cranial nerve. Occasionally branches from the great auricular nerve of the cervical plexus are distributed to the gland.

The submaxillary salivary glands are supplied by branches from the submaxillary ganglion, which receives branches from the seventh cranial nerve through the chorda tympani, from the gustatory branch of the fifth cranial nerve, and from the sympathetic nerve.

The sublingual glands are supplied by branches from the gustatory of the fifth and by branches from the seventh cranial nerve through the chorda tympani, and also by branches from the sympathetic nerve.

The nerves supplying the salivary glands are divided into *vasomotor fibres*, which terminate in the walls of the blood-

vessels and regulate their calibre, and into *secretory fibres*, which pass between, and terminate in, the glandular cells of the glands.

The MUCOUS GLANDS are compound tubular glands; their secretion is viscid and contains mucin; their duct is lined with cylindrical epithelium.

The GLANDS OF THE TONGUE are also compound tubular glands. *Weber's glands*, which are situated near the root of the tongue, are *mucous;* the glands situated near the circumvallate papillæ of the tongue are *serous;* and those situated near the tips of the tongue are *mixed.*

The secretions of the individual glands of the mouth differ. The *secretion of the parotid glands* is clear, but becomes turbid on standing. Its specific gravity is 1003; it consists of 1½ per cent of solids and of water. The principal organic ingredient is *ptyalin;* albumin and traces of urea are also found. The inorganic ingredients are water, bicarbonate of potassium, sodium and potassium chloride, and sulphates and traces of sulphocyanide of potassium or sodium. Its physiological or diastatic action is more powerful than that of the other salivary glands.

The *secretion of the submaxillary glands* is more viscid than that of the parotids, owing to the fact that it contains mucin; it contains less ptyalin than the secretion of the parotids. It contains about ½ to 1 per cent of solids and 99 per cent of water. The organic ingredients are ptyalin, mucin, and epithelial cells. The inorganic ingredients are water, sodium, potassium, and calcium chloride, and traces of the sulphocyanide of potassium.

The *secretion of the sublingual glands* is strongly alkaline in reaction; it is very viscid and contains mucin, salivary corpuscles, and also traces of sulphocyanide of potassium. It contains no ptyalin, and hence possesses little or no diastatic properties.

The *secretion of the mucous glands* contained in the mucous membrane of the cheeks and lips, *and that of the*

glands of the tongue, is alkaline and viscid; it contains water, salts, albuminous matter, mucin, but *no* ptyalin.

The secretion of the salivary glands is called *saliva.* The *mixed saliva* in the mouth contains the secretions of all the glands of the mouth. The physical properties of mixed saliva are as follows: it is colorless, odorless, and viscid; it has an alkaline reaction and a specific gravity of 1005 to 1009.

The amount of saliva secreted in twenty-four hours by the healthy human adult varies greatly; it may be estimated to be from 200 to 1,000 or even 2,000 grammes—that is, from 7 to 50 or 70 ounces.

The chemical composition of mixed human saliva is about as follows:

Water, 995 parts in 1,000.

Organic ingredients, 2.5 to 3.5 in 1,000.

Inorganic solids, 1.5 to 2.5 in 1,000.

The organic ingredients of the saliva are: mucin, serum-albumin, ptyalin, epithelial cells, and salivary corpuscles.

Mucin is the most abundant, ptyalin the most important, organic ingredient of the saliva; the latter is a ferment, giving to the saliva its diastatic property.

The inorganic solids are the salts, namely, sodium and potassium chloride, phosphate of calcium, magnesium, and sodium, and traces of sulphocyanide of potassium and sodium.

A microscopical examination of the saliva reveals the fact that it contains bodies which are not actual but accidental ingredients. These are: 1. Large, rounded, nucleated cellular elements, called *salivary corpuscles;* they originate in the salivary glands.

2. *Epithelial cells* from the mucous membrane of the mouth and tongue.

3. *Micro-organisms,* such as the leptothrix buccalis, the bacillus buccalis, the spirillum sputigenum, and the spirochæte dentium.

The buccal cavity, especially the spaces between the teeth, and cavities of teeth in which particles of food are retained, are a favorable field for the growth and development of these micro-organisms, most of which are deleterious and often cause the decay of the teeth. Frequent cleaning of the mouth and teeth, and the use of antiseptic mouth washes, prevent their development.

The *physiological actions and uses of the saliva* may be enumerated as follows:

1. It has a diastatic action, producing chemical changes in starchy foods.

2. It moistens the food, dissolves portions of the food, and assists in the formation of the bolus.

3. It aids articulation and deglutition.

4. It stimulates the gastric secretion.

The *diastatic action* of the saliva is a chemical one. Starch ($C_6H_{10}O_5$) consists of granules which are composed of cellulose and granulose. Starch granules are insoluble in cold water; when boiled the cellulose is broken up and the liberated granulose forms a paste. Unbroken starch granules are not easily acted upon by the saliva. Starch paste, when brought in contact with saliva, soon becomes liquefied and transparent. The change which takes place is a chemical one, and it consists in the transformation of the starch into *dextrin,* and if the action of the saliva is continued the dextrin is transformed into a sugar called *maltose.* During the transformation of starch into dextrin two varieties of the latter are produced—namely, *erythrodextrin and achroodextrin.* Dextrin has the same chemical formula as starch, but differs in its physical properties. Starch exists in granules, dextrin is obtained as an amorphous powder. Starch is not soluble in cold water, while dextrin is freely soluble in the same. Starch with iodine gives a blue color, erythrodextrin a rose, while achroodextrin has no color reaction

Maltose ($C_{12}H_{22}O_{11}$) is a sugar which differs from grape-

sugar in that it contains one molecule of water less than glucose, and in that its power to reduce metallic salts, such as cupric sulphate, is less than that of grape-sugar. The chemical tests for maltose are, first, *Moore's* or *Trommer's* test, which consists in the addition of liquor kali caustici to the solution; the presence of maltose is indicated by a brown discoloration when the solution is boiled. Second, the test with *Fehling's* solution.

The diastatic action of the saliva is due to ptyalin. *Ptyalin* is an organic nitrogenous substance belonging to the class of ferments. It can be obtained from the saliva in the following manner: first the saliva is acidulated with phosphoric acid, then lime-water is added until a precipitate of calcium carbonate is obtained, and with this the ptyalin will be precipitated. The ptyalin, being soluble in water, can be washed out from the precipitated calcium carbonate, and then it is precipitated from its watery solution by alcohol. Ptyalin so obtained is a white, amorphous powder.

The nervous mechanism of the secretion of the saliva. The secretion of saliva is a *reflex nervous act.* When food is introduced into the mouth, the stimulus is conveyed by the *sensory* nerves of the buccal cavity to the *centre of insalivation*, which is situated in the medulla oblongata; from this centre the stimulus is conveyed to the *secretory* and *vasomotor* nerve-fibres which are distributed to the salivary glands. Stimulation of the seventh cranial nerve and of the chorda tympani produces a profuse flow of a watery secretion, especially from the submaxillary and the sublingual salivary glands, and the vessels of these glands become dilated. Stimulation of the sympathetic nerve produces a scanty secretion from these glands. These facts demonstrate that the seventh cranial nerve and the chorda tympani supply to these glands principally secretory and vasodilator fibres, whereas the sympathetic nerve supplies to them secretory and vasoconstrictor fibres.

Stimulation of the sympathetic nerve does not excite the secretion from the parotid salivary gland. Stimulation of the glosso-pharyngeal nerve, which sends branches to the parotid through the otic ganglion, produces a thick secretion. Stimulation of the facial, which also sends fibres through the otic ganglion to the parotid, produces a profuse watery secretion from that gland. Stimulation of other more distant nerves—for instance, of the pneumogastric—also stimulates or excites the secretion of saliva.

Ordinarily the secretion of saliva is excited by mechanical, chemical, or electrical stimuli applied to the sensory nerves of the mucous membrane lining the mouth.

Introduction of food into the mouth, mastication, and the chewing of substances are the common causes of the flow of saliva. It is often excited simply by seeing or smelling articles of food, or even by thinking of them. Direct stimulation of the centre of insalivation in the medulla oblongata excites the flow of saliva. When the cerebral nerves supplying the salivary glands are severed, a continual secretion takes place for several days until a degeneration of the gland or glands has occurred. This condition is called *paralytic secretion of saliva.* Certain drugs—for instance, atropine and curare—also the stimulation of certain sensory nerves, *inhibit* the secretion of saliva. Other drugs—such as mercurial preparations, pilocarpine—cause an excessive flow of saliva, a condition which is called *ptyalism.* Diseases, ulcers, and inflammation of the mucous membrane of the mouth, also neuralgia, cause an increased flow of saliva.

The mode of the secretion of saliva, and the changes which take place in the glands—*e.g.*, in their histological elements—may be described as follows : The ingredients of the saliva do not all exist as such in the blood conveyed to the gland, but are produced by the cells of the gland from materials of the blood. It has been observed that the glandular cells lining the serous alveoli become larger and

distended during the period of rest, and also that their protoplasm during this time becomes more granular. During the active period or stage of secretion the gland and its granular protoplasm diminish. The theory is that these cells transform materials of the blood into their protoplasm, and that this transforms itself into the ingredients of the saliva, which are not previously found in the blood.

The changes observed in the glandular cells lining the mucous alveoli consist in a swelling of their protoplasm during the stage of rest. The protoplasm of these cells is transformed into mucigen, which, during secretion, is transformed into mucin.

The secretion of saliva during the first two months of infantile life is very scanty, and the saliva at this period possesses but little diastatic property. Infants at this age should for this reason receive no amylaceous food. After the second month the secretion becomes more copious. It is very much increased during dentition, owing to the irritation of the mucous membrane of the mouth.

It has been found that in a disease called thrush the saliva possesses no diastatic action. Thrush is a disease characterized by a whitish deposit on the tongue, gums, and mucous membrane of the mouth as the result of the development of a vegetable micro-organism. The disease occurs in infants as the result of insufficient cleansing of the mouth. Tea has the property of decreasing or destroying the diastatic action of the saliva. It is for this reason that it is more desirable to drink tea after than during meals.

LECTURE XIV.

DIGESTION (*continued*).

4. *Deglutition.*

WHEN the food is masticated and insalivated the bolus is collected upon the tongue and transmitted by muscular action into the pharynx, and from this through the œsophagus into the stomach. The whole process is called *deglutition*, or swallowing.

Deglutition is a muscular act, and the organs concerned in it are the tongue, the soft palate, the pharynx, and the œsophagus.

The *tongue* is a conical-shaped muscular organ situated in the floor of the mouth, its base at the posterior part of the floor of the mouth; its apex protrudes forward. The free surface is covered with mucous membrane. The main mass of the organ is composed of fibres of the *lingualis muscle*, which are inserted in a septum which passes vertically from the apex to the base of the tongue, separating it into halves. The fibres of the lingualis muscle blend with those of the *extrinsic* muscles and pass in a transverse and vertical direction. The delicate motions of the tongue are produced by the contractions of the fibres of the lingualis muscle. The *intrinsic muscles* are the genio-hyoglossus, the hyoglossus, the styloglossus, and the palato-glossus, one of each on either side.

The *genio-hyoglossus* arises from the superior genial tubercles, and from this point its fibres expand in a fan-like manner and are inserted in the under-surface of the tongue; the posterior fibres pass to the hyoid bone. Contraction of the anterior fibres causes protrusion of the tip of the tongue; contraction of the posterior fibres causes

retraction of the tongue; and contraction of the fan-like expanded fibres makes the tongue concave from side to side, forming a channel through which liquids, by suction, pass to the pharynx.

The *hyoglossus* arises from the hyoid bone. Its fibres are inserted in the sides of the tongue, and their contraction draws the sides of the tongue down, thus making its surface convex from side to side.

The *styloglossus* arises from the styloid process of the temporal bone, and its fibres are attached posteriorly to the sides of the tongue. Contraction of these fibres draws the base of the tongue upward and backward.

The *palatoglossus muscles* form the anterior pillars of the soft palate ; their action is similar to that of the styloglossus. The mucous membrane is covered with stratified epithelium. Beneath the mucous membrane are numerous secreting glands, which open on the surface of the tongue, the secretions of which mix with that of the other glands of the mouth.

From the mucous surface of the tongue are projected numerous papillæ, which are organs of the special sense of taste.

The motor nerves of the tongue are branches from the hypoglossal or twelfth cranial nerves which are distributed to the extrinsic muscles, and branches from the seventh cranial nerve through the chorda tympani which are distributed to the fibres of the lingualis muscle. The tongue assists in the act of mastication by conveying the food between the teeth. It also assists in the insalivation of the food by its various motions. In the act of deglutition its motions are most important.

The functions of the tongue as an organ of special sense I will describe later.

The *soft palate* is suspended from the posterior border of the hard palate. It forms the arched roof of the posterior

part of the buccal cavity, and an incomplete septum between the buccal and pharyngeal cavities.

The soft palate is composed of a central tendinous portion and five muscles on each side. The free surfaces are covered with mucous membrane: that of the lower, or buccal surface, is covered with stratified squamous epithelium; that of the upper surface—viz., that which is directed toward the respiratory passages—is covered with ciliated epithelium.

The five pairs of muscles of the soft palate are: the tensores palati, the levatores palati, the azygos uvulæ, and the palato-glossus muscles, forming the anterior pillars, and the palato-pharyngeus muscles, forming the posterior pillars. The space between the pillars is called the *isthmus of the fauces.*

The action of these muscles is of the greatest importance in the first stage of the act of deglutition. To some extent the name of these muscles explains their action.

The motor nerves to the muscles of the soft palate are branches received through Merkel's ganglion and through the otic ganglion.

The *pharynx* is a musculo-membranous sac, conical in shape, with its base directed upward and its apex directed downward. It is about 4½ inches long, and broader in its transverse than in its antero-posterior diameter. It is attached above to the sphenoid bone and to the basilar process of the occipital bone; posteriorly it is attached to the cervical vertebræ; below it is continuous with the œsophagus; laterally it is attached to the styloid processes of the temporal bone, and in front to the larynx, hyoid bone, tongue, to the inferior maxillary bone, and to the pterygoid process of the sphenoid bone.

The pharynx is composed of three coats—an internal mucous, a middle muscular, and an external fibrous. The mucous membrane of the pharynx is covered above the soft palate with ciliated, columnar, and below the soft palate

by squamous, epithelium. The pharynx communicates by seven openings with the nasal, aural, and buccal cavities, and with the larynx and the œsophagus.

The muscles of the pharynx are the superior, inferior, and middle constrictors, and the stylo-pharyngeus and palato-pharyngeus on each side. The action of the constrictors is the contraction upon the bolus, thus forcing it into the œsophagus. The action of the stylo-pharyngeus and palato-pharyngeus is the raising of the pharynx.

The motor nerves supplying the pharyngeal muscles are branches from the tenth cranial or pneumogastric nerves.

The *œsophagus*, or gullet, is a musculo-membranous tube about 9 inches long. It extends from the space between the fifth and sixth cervical vertebræ to the ninth dorsal vertebra. It is situated in front of the spinal column, passes through the neck into the thoracic cavity, in which it descends through the posterior mediastinum, then passes through an opening in the diaphragm, and terminates at the cardiac opening of the stomach. The œsophagus has also three coats—namely, an external muscular, a middle fibrous or areolar, and an internal or mucous. The latter is arranged in longitudinal folds and is covered with stratified pavement epithelium. Beneath the mucous coat are a layer of non-striated muscular fibres and a number of glands.

The muscular coat consists of an external layer of longitudinally arranged fibres and an inner layer of circular fibres. In the upper part of the œsophagus the muscular fibres are of the striated, voluntary variety ; those in the lower part are non-striated and not under the control of the will.

The motor nerve supply to the œsophagus is by branches from the tenth cranial or pneumogastric nerves.

The act of deglutition consists of three distinct stages. The *first stage* consists in the transmission of the bolus

from the mouth through the isthmus of the fauces into the pharynx. This takes place in the following manner :

1. The mouth is closed by the contraction of the orbicularis oris muscle.

2. The lower jaw is fixed against the upper jaw by the contraction of the elevators of the lower jaw, and the pharynx, larynx, and hyoid bone are raised.

3. The tongue, with the bolus upon its dorsum, is pressed against the palate, and then the bolus is forced down the inclined plane through the isthmus of the fauces into the pharyngeal cavity.

4. The anterior pillars—*e.g.*, the palato-glossus muscles—contract, and thus prevent the forcing back of the bolus into the buccal cavity.

The upper opening of the larynx is closed, during the stage of deglutition, by the epiglottis, which is pressed against the opening by the raising of the larynx and hyoid bone and by the raising of the root of the tongue. Particles of food are thus prevented from passing into the larynx.

The *second stage* consists in the grasping of the bolus by the constrictors of the pharynx, and the forcing of it into the œsophagus by the peristaltic contraction of the constrictors. The food is prevented from entering the nasopharyngeal cavity by the contraction and elevation of the posterior pillars of the palato-pharyngeus muscles, which thus form a septum between the upper and lower part of the pharynx.

The *third stage* of deglutition consists in the forcing of the food through the œsophagus into the stomach by the peristaltic contraction of the muscular fibres of the œsophagus, which contract above the bolus and thus force it onward.

Deglutition is partly a voluntary, partly an involuntary nervous act.

The first stage is *voluntary*, the second and third *involuntary*.

The *centre of deglutition* is located in the medulla oblongata.

The sensory nerves are branches from the fifth cranial nerve supplying the soft palate, branches from the ninth cranial nerve supplying the tongue and pharynx, and branches from the sympathetic nerve.

The motor nerves are branches from the fifth, seventh, ninth, tenth, and twelfth cranial nerves supplying the muscles of mastication, and those of the tongue, palate, pharynx, larynx, and the œsophagus.

5. *Stomach Digestion.*

The digestive processes which take place in the stomach are described as the *stomach digestion*, or the *chymification*.

The *stomach* is the dilated portion of the alimentary canal which is situated between the lower end of the œsophagus and the small intestines. The stomach is located in the abdominal cavity, occupying the region of the epigastrium, and extending transversely from the left to the right hypochondrium. The stomach is about 12 inches long and 4 inches wide at its widest part; it presents for examination 2 extremities, the pyloric and the cardiac: 2 openings, the cardiac and the pyloric; 2 borders, the upper and lower; and 2 surfaces, the anterior and posterior.

The *cardiac extremity*, also called the *left*, *greater*, or *splenic* extremity, extends into the left hypochondrium and is in contact with the spleen; it presents a pouch-like expansion, which is called the *cardia* or the *fundus*.

The *pyloric extremity*, also called the *right* or *lesser* extremity, is situated a little to the right of the linea alba, behind the abdominal wall; it is in contact with the under-surface of the liver.

The *cardiac* or *œsophageal opening* of the stomach communicates with the œsophagus; it has the form of an inverted funnel, and is situated about 1 inch to the left of

the sternum, behind the costal cartilage of the seventh rib. The cardia of the stomach extends from 2 to 3 inches to the left of this opening.

The *pyloric opening* communicates with the duodenum of the small intestines; it is a circular opening in the pyloric extremity.

The *upper border*, also called the *lesser curvature*, is concave and extends from the cardiac to the pyloric opening.

The *lower* or *greater curvature* is convex.

The *anterior surface* of the stomach is directed forward and a little upward; it is in relation with the abdominal wall, with the under-surface of the left lobe of the liver and of the diaphragm.

The *posterior surface* is directed backward and downward, and is in relation with the pancreas, the solar nerve plexus, and the large abdominal vessels.

The position of the stomach, and its relations to the abdominal viscera, vary with the condition of the stomach.

The stomach is held in its position by a fold of peritoneum called the *gastrophrenic ligament* and by the *lesser omentum*.

The walls of the stomach are composed of four coats—namely, the *serous*, *muscular*, *areolar*, and *mucous*.

The *serous* coat is derived from the peritoneum; it covers the entire organ, except at the borders where the omentum is attached.

The *muscular* coat consists of non-striated fibres, which are arranged longitudinally, circularly, and obliquely.

The *longitudinal* fibres are continuous with the longitudinal fibres of the œsophagus; they spread over the curvatures and extremities and are continuous as the longitudinal muscular fibres of the duodenum.

The *circular* fibres are situated beneath the longitudinal fibres and surround in a layer the whole organ; they are most abundant around the pylorus, where they protrude into the lumen of the latter and form, with the mucous covering, the *pyloric valve*.

The *oblique* fibres pass obliquely from left to right of the cardia and whole splenic end of the stomach.

The contraction of the muscular fibres produces the peristaltic movements of the stomach, by which its contents are well mixed with the gastric juice and are transmitted through the pyloric opening into the duodenum.

The *areolar* coat is situated between the muscular and the mucous coats; it serves to support the blood-vessels of the stomach, and is also called its *vascular* coat.

The *mucous* coat of the stomach is thrown into numerous longitudinal folds called the *rugæ;* these become unfolded when the stomach is distended, and its mucous lining then presents a smooth surface.

The mucous membrane of the stomach consists of an *areolar submucous* coat, a layer of non-striated mucous fibres called the *muscularis mucosæ*, these covered by a single layer of columnar epithelial cells resting upon a delicate basement membrane.

When examined under the microscope the surface of the mucous membrane has a velvety appearance; it shows many shallow depressions, which are called *alveoli;* in the bottom of these are seen the delicate openings of the secreting glands of the mucous membrane. The alveoli are separated by slightly elevated ridges.

The secreting glands of the stomach are called *gastric* follicles. The human stomach has two varieties of these, called respectively the *pyloric* and the *peptic* glands; they differ in their structure, distribution, and secretion.

The *pyloric* glands are, as the name implies, located near the pylorus. They are branched, tubular glands consisting of two or three convoluted tubules which open into one common duct, which is about the same length as the tubules. The gland consists of a delicate basement membrane, which is lined with epithelial cells. The duct and mouth of these glands are lined with a columnar epithelium; the secreting portions of the gland—*e.g.*, the tubules

—are lined with short columnar or cubical glandular epithelial cells which have a granular protoplasm and do not occlude the lumen of the glands. The whole gland is supported by areolar and adenoid tissue, and in its lower portion is surrounded by fibres of the muscularis mucosæ.

The *peptic* glands, or *fundus* glands, are most numerous near the fundus; they consist also of from three to four tubules, which open into one common duct. The tubules in this variety are not convoluted, and the duct is shorter and only about one-third of the length of the tubules. The neck—the portion where duct and tubules join—is constricted. The duct is lined with columnar epithelium, and the secreting portion of the gland with two kinds of cells, called the parietal cells and the central or chief cells.

The *chief* or *central* cells form in a continuous layer the inner lining of the secreting portion of these glands; they are short, cubical, polyhedral, or columnar nucleated cells which have a granular protoplasm.

The *parietal* cells are large, ovoid, and nucleated cells and have a granular, reticulated nucleus; they are situated between the layer of central cells and the membrana propria; they do not form a continuous layer, but, owing to their large size, cause a bulging-out of the basement membrane These cells are also called the acid-forming cells of *Langley*. Between their tubules, in a submucous tissue, are collections of lymphoid tissue which resemble the solitary glands of the intestines.

The blood supply of the stomach is from branches of the cœliac axis, the second branch of the abdominal aorta, as follows:

1. The gastric artery.

2. The hepatic artery, which gives to the stomach the pyloric artery and the arteria epiploica dextra.

3. The splenic artery, which gives to the stomach the arteria epiploica sinistra and the vasa brevia. These arteries anastomose freely and supply the muscular coat. In

the submucous coat they form capillary plexuses around the tubules of the secreting glands, and then secondary plexuses are formed around the necks and ducts of these glands. From these secondary plexuses the veins arise, and, pursuing the same course backward, return the blood from the stomach by the superior mesenteric and splenic veins into the portal vein.

The nerve-supply of the stomach is from the gastric branches of the tenth cranial or pneumogastric nerve, and from branches of the solar plexus of the sympathetic nerve. Plexuses composed of non-medullated nerve-fibres and ganglion-cells are contained in the muscular and areolar coat; they are called respectively *Auerbach's* and *Meissner's* plexus.

Lymphatics and collections of adenoid tissue are distributed in the coats, especially in the submucous or areolar coat.

LECTURE XV.

DIGESTION (*continued*).

The Gastric Juice.

THE secretion of the glands of the stomach is called the *gastric juice*. Gastric juice is not secreted continuously, but only at such times as the mucous membrane is irritated by stimuli, either chemical, thermal, or mechanical; ordinarily the introduction of food, or even of indigestible substances, excites the secretion of gastric juice.

The quantity of gastric juice secreted in a certain time varies greatly. It has been estimated that a healthy human adult taking food in proper quantity and quality, and at regular intervals, secretes from 10 to 20 pints of gastric juice in twenty-four hours.

The physical properties of gastric juice may be said to be as follows: gastric juice is a clear, yellowish liquid, having a specific gravity of 1010, a decided acid reaction, and a peculiar odor.

The chemical composition of gastric juice is as follows:

- Water, 994.4.
- Inorganic salts, 2.2.
    - Sodium chloride.
    - Potassium chloride.
    - Calcium chloride.
    - Ammonium chloride.
    - Calcium phosphate.
    - Magnesium phosphate.
- Pepsin, 3.2.
- Free hydrochloric acid, 0.2.

The water and inorganic salts pre-exist as such in the

blood and are secreted by the gastric glands. Pepsin and hydrochloric acid do not pre-exist in the blood, but are formed by the secreting cells of the gastric glands.

Pepsin is an organic nitrogenized substance belonging to the class of ferments. It can be obtained by precipitating it from its solution with alcohol or by extracting it from the stomach mucous membrane with glycerin.

Pepsin is a proteolytic ferment—*i.e.*, one which causes a change of proteids into peptones, but it does so only in an acid medium. Pepsin is formed from materials of the blood by the cells lining the secreting portions of the fundus and pyloric glands; in the fundus glands the pepsin is formed in the central or chief cells. The granular protoplasm of the cells which produces the pepsin is composed of a substance called *zymogen* or *propeptone.* It has no proteolytic property, but is transformed into pepsin in the presence of hydrochloric acid.

The *hydrochloric acid* of the gastric juice is formed from sodium chloride of the blood by the ovoid parietal cells of the fundus glands. Its exact mode of formation in these cells is unknown.

Maly showed that in a mixture of lactic acid and chlorides small portions of hydrochloric acid would form upon the addition of water, and this was thought to explain the presence of the hydrochloric acid in the gastric juice. But it has been shown that lactic acid is only an accidental ingredient of the gastric juice; it is only formed in the stomach as a product of the decomposition of certain substances, and its formation can be prevented and still the gastric juice will contain hydrochloric acid. These facts tend to disprove Maly's theory. Since the discovery that two kinds of secreting glands exist in the stomach, it has been demonstrated beyond a doubt, by *Heidenheim* and others, that the HCl is formed in or by the ovoid parietal cells of the fundus glands as the result of their special physiological property. Gastric juice, as taken from the

stomach, also contains *mucus*, which is constantly secreted by the goblet-cells which are located between the columnar epithelial cells. *Lactic* acid, also *acetic* and *butyric* acid, are formed in the gastric juice as accidental ingredients.

The secretions from the fundus and pyloric glands differ: that of the fundus glands contains pepsin and hydrochloric acid and has an acid reaction; that of the pyloric glands has a neutral or alkaline reaction, contains *no* hydrochloric acid, and a small amount of pepsin only, consequently it has a smaller digestive property than the secretion from the fundus glands.

Natural gastric juice is obtained by means of a gastric fistula.

Artificial gastric juice is formed by adding a quantity of pepsin or glycerin-pepsin extract to a solution acidulated with dilute HCl.

The action of the gastric juice upon the food is chiefly the conversion of proteids into peptones.

Proteids are insoluble and non-diffusible albuminous or albuminoid substances; these in an acid solution are transformed into acid-albumin, and finally, by the action of the ferment pepsin, into *peptones*.

The chemical change which takes place in this transformation is called *hydration;* pepsin is therefore a *hydrolytic* ferment.

During the transformation of proteids into peptones a series of intermediate products are formed which have received various names. According to *Kühne* the albuminous or albuminoid substances are first divided into *hemi-albuminose* and *anti-albuminose*; these are then converted into *hemi-peptone* and *anti-peptone.*

During pancreatic digestion the *hemi-peptone* is further separated into two organic nitrogenous products—namely, *leucin* and *tyrosin;* this is probably due to a difference in the molecular constitution of the two peptones.

The physical and chemical properties of the peptones are

as follows: Peptones are soluble in water, are diffusible, and can be precipitated from their solution upon the addition of chloride of mercury.

The chemical test generally used to determine the presence of peptone in a solution is the *Biuret* test, which is as follows: to the suspected solution add a few drops of a concentrated solution of potassium hydrate, and then a few drops of a 10 per cent solution of cupric sulphate, and when heat is applied a violet coloration indicates the presence of peptone.

Peptone has the same characteristics, whether formed from the albuminous or albuminoid ingredients of meats, vegetables, milk, eggs, etc.

During the process of stomach digestion almost all the ingredients of food are disintegrated, but only the albuminous and albuminoid substances are actually changed and made absorbable. The digestibility of the various articles of food depends largely upon their preparation.

Meats swell, the connective tissue is dissolved by the gastric juice, and the muscular fibres are then gradually dissolved.

The connective tissue of fried and broiled meats is dissolved more quickly than that of boiled meats.

Adipose tissue is attacked by the gastric juice, the fibrous connective-tissue network is dissolved, and the fat-globules are set free.

Milk curdles when introduced into the stomach, owing to the coagulation of the casein ; this is gradually liquefied by the digestive property of the gastric juice.

Eggs are most digestible when soft-boiled, which process coagulates the albuminous ingredients of the egg into fine flakes, which are easily and rapidly dissolved in the gastric juice. But the long boiling of eggs coagulates their albumen into a hard mass requiring a long time for its liquefaction by the gastric juice. The albumen of raw eggs

coagulates in the stomach into a semi-solid colloid mass which also is very slowly digested.

Bread contains principally carbohydrate material and legumin, the vegetable albuminous substance. The latter is dissolved by the gastric juice, and the carbohydrates are set free.

Vegetables are also attacked by the gastric juice ; their nitrogenous matter is digested, and oleaginous and amylaceous ingredients are set free.

The duration of the stomach digestion varies. It depends upon the quality, quantity, and manner of preparation of the food. It is estimated that from four to six hours are required for the gastric digestion of a hearty meal composed of various articles of food.

The action of the gastric juice upon the various articles of food results in the formation of a thickish fluid which has an acid reaction and odor. It is called the *chyme.* This consists of water, gastric juice, together with dissolved sugar, dextrin, acid-albumin, peptone, drops of liberated fat, and softened masses of undigested food. It is essential that with the meals, or shortly after, a certain quantity of liquid be taken, which serves to give to the stomach contents a certain fluidity which is necessary for the absorption of digested materials. The quantity of liquid required for this purpose is best regulated by the thirst which the individual has when taking solid foods.

In many gastric disorders gases develop in the stomach as the result of an undue fermentation or decomposition of foods. Normally the gastric juice, owing to the antiseptic properties it possesses, prevents this decomposition, and it is believed by some that this is the most important property of the gastric juice.

The uses of the gastric juice may be enumerated as follows :

1. It converts proteids into peptones.
2. It softens and disintegrates the food.

3. It acts as an antiseptic.

The digestion of the food in the stomach, and the action of the gastric juice upon all foods, are evidently only preparatory for the intestinal digestion.

The chyme contains many insufficiently digested and entirely undigested materials, which undergo further changes in the intestinal canal.

The *peristaltic* movements consist of a peculiar rhythmical contraction of the muscular fibres of the walls of the stomach. By these movements the food becomes thoroughly mixed with the gastric juice, and the chyme is conveyed into the duodenum through the pyloric opening, which opens periodically by the relaxation of the circular muscular ring and fold of mucous membrane which constitute the pyloric valve. The œsophageal or cardiac opening of the stomach is closed by the contraction of its circular muscular fibres during the process of stomach digestion.

The nervous mechanism of the stomach is quite complicated. The motions of the stomach are produced by the activity of the automatic ganglia and plexuses which are contained in the walls of the stomach and which communicate with the vagi and sympathetic nerves. Experiments have shown that such automatic ganglia control the contraction and relaxation of the fibres of the openings of the stomach, and that other ganglia control the peristaltic motions of the muscular walls. Experiments have demonstrated that these centres or ganglia probably communicate through the pneumogastric nerves with nerve-centres in the brain. This explains the reflex influence of mental emotions upon the digestion.

The secretion of the gastric juice is generally excited by the introduction of food into the stomach. The mucous membrane becomes turgid and red, caused by a dilatation of the blood-vessels. Section of the pneumogastric nerves at this stage causes a contraction of the walls of the blood-vessels and a cessation of the secretion, but this is only

temporary. Section of both the pneumogastric and sympathetic nerve-branches of the stomach is not followed by any serious or permanent effects on the secretion of the gastric juice or on the movements of the stomach. Stimulation of these nerves does not demonstrate any positive result as to their effect on the activity of the stomach and its glands. It must therefore be supposed that the motor and secretory fibres are derived from the ganglia in the walls of the stomach. The motions of the stomach and the secretion of its glands are reflex nervous acts. Irritation of certain peripheral nerves sometimes produces an abnormal contraction of the muscular walls of the stomach, resulting in an expulsion of the contents through the œsophagus, pharynx, and mouth—an act which is called vomiting.

Vomiting is caused by a contraction of the muscular walls of the stomach: the pyloric opening is closed by the contraction of the muscular fibres of the valve; the food is forced toward the cardia, which is distended; this finally contracts and forces the contents of the stomach through the cardiac opening into the œsophagus. Vomiting is excited by chemical or mechanical irritation of the sensory nerves supplying the mucous membrane of the palate, tongue, pharynx, or stomach. Irritation of the uterus, of the intestines, and of the peritoneum often causes vomiting. It is also caused by the direct irritation of a nerve-centre which is located in the medulla oblongata and is called the *centre of vomiting;* this centre is located near the centre of respiration, and it is believed that it is for this reason that the feeling of vomiting can often be overcome by taking deep inspirations. Vomiting also stimulates the respiratory centre, and emetics are often given to eliminate mucus, etc., from the respiratory passages.

Emetics are drugs which are given to cause vomiting; they do so either by their effect on the central nervous system, like apomorphia, or by their irritating effect on the

mucous membrane of the stomach, like cupric sulphate or tartar emetic. Cerebral irritations caused by sights or thoughts, or diseases of the brain, also produce vomiting.

In post-mortems performed on persons who have died during the process of stomach digestion, it has been found that the walls of the stomach have been attacked by the gastric juice, and the question arises, Why does not the gastric juice attack or digest the walls of the stomach during life? Various theories have been advanced as an answer to this question. Some believe that the layer of mucus which constantly covers the mucous lining of the stomach prevents this; others think that the alkalinity of the blood, with which the walls of the stomach are so freely supplied, is sufficient to neutralize the acidity of the gastric juice; but it is not improbable that the epithelium covering the mucous lining of the stomach possesses a special protecting property against the action of the gastric juice.

LECTURE XVI.

DIGESTION (*continued*).

6. *Intestinal Digestion.*

The contents of the stomach—*i.e.*, the chyme—as they pass through the pyloric opening into the intestinal canal, contain many undigested and insufficiently digested materials, which in the intestinal canal undergo further changes and are rendered absorbable by the action of the digestive juices which are poured into the intestinal canal. The changes which the food materials undergo in this portion of the digestive tract are described as the *intestinal digestion.*

The *intestinal canal* is about 25 feet long and is divided into the small and large intestines; this division indicates a difference in the diameter, not in the length, of the two portions of the intestinal canal.

The *small intestines* are about 20 feet long; they begin at the pyloric opening and are continuous with the large intestines. The small intestines are again divided into *three portions*, called respectively the duodenum, the jejunum, and the ileum.

The *duodenum*—so called from the fact that it is about twelve fingers' breadth in length—is horseshoe-shaped and embraces the head of the pancreas. It consists of an *ascending portion*, which passes to the under-surface of the liver; a *descending portion*, which passes in front of the right kidney; and a *transverse portion*, which passes obliquely from right to left in front of the second and third lumbar vertebræ, where it becomes continuous with the jejunum.

The *jejunum* is so called from the fact that it is generally found empty after death; its length is about 8 feet, or about two-fifths of the length of the remaining portion of the intestinal canal. The convolutions of the jejunum are located principally in the umbilical and right iliac regions of the abdominal cavity.

The *ileum* is so called from its many convolutions, which are located in the umbilical, hypogastric, and right iliac regions of the abdominal cavity. The ileum is continuous with the large intestines in the right iliac fossa. The point of communication is guarded by a fold of mucous membrane which is called the *ileo-cæcal valve*.

The small intestines are held in position by a fold of the peritoneum called the *mesentery*. The duodenum is more firmly fixed than any portion of the small intestines.

The walls of the small intestines are composed of four coats—namely, a serous, a muscular, an areolar, and a mucous coat.

The *serous* coat is derived from the peritoneum. It covers the entire external surface of the intestinal canal, except at the border where the mesentery is attached, and at some points of the duodenum.

The *muscular* coat consists of fibres of the non-striated variety. They are arranged in an *external longitudinal* and an *internal circular* layer; the latter forms incomplete rings around the intestinal tube.

The *areolar* coat is contained between the muscular and mucous coats; it serves to support vessels, glands, etc.

The *mucous* coat consists of a layer of non-striated muscular fibres (the *muscularis mucosæ*), of an areolar layer (the *submucosæ*), and of a single layer of columnar epithelial cells resting on a delicate basement membrane.

The mucous membrane of the small intestines is arranged in circular folds. They are called *valvulæ conniventes*, and serve to provide a large surface for secretion and absorption, and also to prevent food from passing too

quickly through the intestinal canal. In order to accomplish this these mucous folds form incomplete circular rings, which are arranged transversely to the long axis of the intestinal tube. They do not unfold on distension of the intestines.

From the mucous membrane of the small intestines are projected minute, cone-like elevations which give to it a velvety appearance. These delicate projections are called *villi.* They are organs intended for the absorption of the saponified oils and fats.

A microscopical examination of the mucous membrane of the small intestines shows that between the villi there are minute openings, which are the orifices of the secreting glands of the small intestines.

The intestinal *juice* is secreted by two sets of glands—namely, the *simple follicles* or *crypts of Lieberkühn* and the *duodenal or Brunner's glands.*

The *simple follicles* or *crypts of Lieberkühn* are distributed throughout the whole intestinal canal. They are simple, finger-like depressions of the epithelial lining of the intestines, and consist of a basement membrane covered with a single layer of cylindrical secreting epithelial cells which have a glandular protoplasm and large, clear, oval nuclei. Between these cells are scattered so-called *goblet-cells.*

The *duodenal* or *Brunner's* glands are of the branching tubular variety. They consist of a number of convoluted tubules, which open into one common duct. The structure of these glands is similar to that of the pyloric glands.

In the areolar coat of the small intestines are small, oval bodies composed of adenoid or lymphoid tissue. They are called *solitary glands.* They sometimes form slight oval elevations of the mucous membrane, which are covered with numerous villi and surrounded by openings of the secreting glands. These are most abundant in the ileum near the ileo-cæcal valve. In these regions there are often found

collections of from 20 to 30 such solitary glands in one mass ; these are called *agminate glands* or *Peyer's patches.*

The lumen of the small intestines diminishes gradually from its beginning to its termination.

The *large intestines* are about 5 to 6 feet long. They begin at the termination of the small intestines in the right iliac fossa and terminate at the anus. The large intestines are also divided into three portions—namely, the cæcum, the colon, and the rectum.

The *cæcum*, or *caput cæcum coli*, which means the blind head of the colon, is a pouch-like expansion which is situated in the right iliac fossa and communicates with the small intestines, the opening of communication being guarded by a reduplication of mucous membrane, called the *ileo-cæcal valve.* From the posterior wall of the cæcum is projected an appendix, called the *appendix vermiformis.* This is from 3 to 5 inches long, with a diameter of about that of a goose-quill. It communicates with the cæcum and is lined with mucous membrane continuous with that of the cæcum. In the cæcum and the appendix are found solitary and agminate glands.

The *colon* begins in the right iliac fossa, and passes from here as the *ascending portion* up to the under-surface of the liver, where it forms the *hepatic flexure ;* then it passes as the *transverse colon* to the spleen, forms here the *splenic flexure,* and then passes down into the left iliac fossa, where it forms the *sigmoid flexure,* which is continuous with the rectum.

The *rectum* is the last portion. It is about 6 inches long and terminates at the anus.

The walls of the large intestines consist of the same four coats as the walls of the small intestines.

The longitudinal fibres of the large intestines are arranged in three flat bands and give to the intestinal tube a sacculated appearance. The circular fibres form a uniform layer and are most abundant at the lower portion of

the rectum, where they form the internal sphincter of the anus. The mucous membrane of the large intestines is also thrown into circular folds, particularly at the sac-culations. The glands of the large intestines are solitary and agminate glands and simple follicles ; the latter differ from those of the small intestines in that they are larger and have a greater number of goblet-cells scattered in the epithelial lining. The secretion of the follicles of the large intestines is for this reason more tenacious and slimy than that of the follicles of the small intestines. The mucous membrane of the large intestines is smooth ; no villi are projected from its surface. The blood-supply to the small and the large intestines is by branches from the superior and inferior mesenteric arteries. The venous blood is conveyed into the portal vein through the superior and inferior mesenteric veins.

The nerve-supply to the intestines is from the superior mesenteric plexus of the sympathetic nerve, branches of which enter the walls of the intestines together with the vessels, and communicate with nerve-plexuses which are situated in the muscular coat. They are called *Auerbach's* plexuses, and these again communicate with *Meissner's* plexuses, which are situated between the muscular and the mucous coats ; from these filaments are distributed to the glands, mucous membrane, etc.

The secretion of the glands of the intestinal canal is called the *intestinal juice*, or *succus entericus*. This may be obtained by an intestinal fistula.

The *intestinal juice* is a yellowish, alkaline fluid which has a specific gravity of 1011 and contains about 2 to 2½ per cent of solids. It is composed of water, alkaline salts, and albuminous matter—namely, mucin and ferment substances of an unknown nature.

Intestinal juice must be considered mainly as the secretion of *Lieberkühn's* follicles. The nature of the secretion if *Brunner's* glands is not exactly known.

The uses of the intestinal juice may be enumerated as follows:

1. It converts proteids into peptones. This action is due to a ferment which acts only in an alkaline medium.

2. It changes starch into sugar, and maltose into glucose. These changes are also due to a ferment. The diastatic property of intestinal juice is not as pronounced as that of the saliva or pancreatic juice.

3. It changes cane-sugar and lactose into levulose or inverted sugar. This transformation is caused by the presence of a ferment called *invertin.*

Besides the intestinal juice there are two other digestive juices which have a part in the process of intestinal digestion; these are the *pancreatic juice* and the *bile*, which are secreted by the accessory glands—viz., by the pancreas and the liver—and are poured into the small intestines.

The *pancreas*, or *abdominal salivary gland*, is situated in the abdominal cavity in the posterior part of the epigastric region and in relation with the lower and posterior portion of the stomach. The gland is hammer-shaped and has a head, a body, and a tail. The *head*, or *right extremity*, bends downward and is embraced by the duodenum; the *body* passes across the lower border of the stomach to the left; and the *tail*, or tapered end of the gland, extends to the spleen. The head is sometimes detached and forms a separate part, called the *lesser pancreas.*

The pancreas is from 6 to 8 inches long and weighs from 3 to 5 ounces.

The structure of the pancreas is similar to that of the salivary glands. It is, like these, a gland of the compound tubular or compound racemose variety. The gland is pierced by a central duct, called *Wirsung's duct*, which passes from the tail portion to the head and opens into the duodenum about 10 centimetres from the pyloric opening.

The gland consists of *lobules*, each of which has a duct (the *lobular duct*) which opens into the main duct of the gland. This divides into minor tubules, called the *intra-*

lobular ducts, and each of these terminates in a pouch-like expansion, the *alveolus*.

These various portions of the gland are composed of a delicate basement membrane and are lined with epithelial cells. The ducts, ductules, and tubular portions of the gland are lined with columnar epithelium.

The alveoli are lined with a single layer of columnar secreting cells. The body of these cells shows two distinct zones—namely, a granular zone toward the lumen of the alveolus, and a clear, homogeneous zone which is directed toward the basement membrane of the alveolus. At the junction of these two zones is situated a large, oval nucleus. *Heidenhain* observed that during the first period—that is, from the sixth to the tenth hour—of intestinal digestion, when the secretion of the pancreas is most active, the granular inner zone of the epithelial cells lining the alveoli decreases, and that after that period it again gradually increases. It is believed that the outer, homogeneous zone takes materials from the blood, which are transformed into the granular protoplasm of the inner zone which forms the ingredients of the secretion of the gland.

The various structures of the pancreas are held together by areolar tissue, which also supports the vessels and nerves of the gland.

The blood-supply of the pancreas is from branches of the splenic, hepatic, and superior mesenteric arteries. The veins open into the portal vein.

The nerve-supply is from fibres of the splenic plexus of the sympathetic nerve. The exact distribution and termination of the nerve-filaments in the gland is unknown.

The *pancreatic juice* is obtained by means of a fistula. It is a colorless and odorless liquid, having a saline taste, a strong alkaline reaction, and a specific gravity of 1010 to 1015. It contains from 6 to 10 per cent solid ingredients, of which nine-tenths are organic and one-tenth inorganic material. The large amount of albuminous ingredients

causes the pancreatic juice to coagulate into a jelly like mass when heated.

The composition of the pancreatic juice is as follows :

Water	911.
Organic matter	81.
Namely, serum-albumin and ferments.	
Inorganic salts	8.
Namely, sodium chloride, sodium carbonate, magnesium phosphate, calcium phosphate	

The ferments of the pancreatic juice are trypsin, amylopsin, and steapsin.

Pancreatic juice, in the presence of the various bacteria existing in the intestinal canal, easily decomposes owing to its great percentage of albuminous material. The juice then assumes a brownish color and a fetid odor, which is due to the formation of fetid gases and to the production of two decomposition products of albuminous substances. These are called *indol* and *skatol.*

The actions and properties of pancreatic juice are as follows :

1. Starch is transformed into sugar. This diastatic action is due to the ferment called *amylopsin.*

2. Proteids are converted into peptones. The proteolytic ferment causing this change is called *trypsin.* It differs from pepsin in that it acts only in an alkaline medium. During the pancreatic digestion the proteids are first transformed into alkali-albumin, which is separated into hemi- and anti albumin, and this finally is converted into anti- and hemi-peptone. During the pancreatic digestion two organic nitrogenous substances, called *leucin* and *tyrosin,* are formed as products of the continued action of pancreatic juice on hemi-peptone.

3. Fats and oils are separated into glycerin and fatty acids. Thin the latter with the alkaline salts present, saponify, and with water form an absorbable emulsion.

The division of the fats is caused by the presence of a ferment called *steapsin.*

The ferments of the pancreatic juice are also called *enzymes.* They do not pre-exist in the blood, but are found in the secreting cells from materials taken from the blood. The granular protoplasm of the inner zone of the secreting cells lining the alveoli of the pancreas is called *zymogen;* as such, it possesses none of the characteristic properties of the enzymes, but it is transformed into these during secretion.

Pancreatic juice is not secreted continuously, but only when food is taken. The secretion gradually increases during the first ten hours, when it begins to decrease again.

The quantity of pancreatic juice secreted in twenty-four hours has not been exactly determined, but it is certainly much more scanty than that of the other digestive juices.

The pancreatic secretion is a reflex nervous act. Ordinarily the introduction of food is the stimulus. During secretion the gland becomes red and enlarged, owing to a dilatation of the blood-vessels.

Extirpation of the pancreas causes *diabetes mellitus.*

LECTURE XVII.

THE DIGESTION (*continued*).

The Bile.

The third digestive juice which takes part in the intestinal digestion is the *bile;* it is secreted by the liver, and is conveyed into the gall-bladder and thence into the duodenal portion of the small intestines.

The *liver* is the largest secreting gland in the body; it weighs about 1,600 grammes and is situated in the abdominal cavity, occupying the left hypochondriac and part of the epigastric regions. The upper, convex surface of the liver is in relation with the under-surface of the diaphragm; the lower, concave surface, with the stomach, duodenum, and the hepatic flexure of the colon; and its anterior, lateral, and posterior surfaces, with the parietes of the abdominal cavity.

The liver is held in position by five ligaments; these are, the *longitudinal,* the *coronary,* the *two lateral,* and the *round* ligaments. The first four mentioned ligaments are folds of peritoneum; the round ligament is the obliterated umbilical vein.

The liver is made up of five lobes; these are called the *right* lobe, the *left* lobe, the *lobus quadratus,* the *lobus caudatus,* and the *lobus Spigelii.*

The five lobes of the liver are separated by five fissures: namely, the *transverse* fissure, the *longitudinal* fissure, the *fissure* for the *gall-bladder,* the *fissure* for the *ductus venosus,* and the *fissure* for the *inferior vena cava.*

The liver is covered with a layer of peritoneum, beneath which is a layer of fibrous tissue, the visceral layer of

which sends numerous prolongations into the substance of the liver, forming numerous small compartments which are filled with liver-tissue and form the lobules. The fibrous covering and the compartments formed by its prolongations are called *Glisson's capsule;* a reflexion of this forms a sheath for the structures entering and leaving the liver at its transverse fissure.

A *liver lobule* is oblong, about one-twelfth of an inch in diameter, and is made up of the following structures:

1. The hepatic cells.
2. A capillary plexus of the portal vein.
3. A capillary plexus of the hepatic artery.
4. The bile-channels, which are formed by adjacent sides of the hepatic cells.

These structures are held together and the whole lobule is surrounded by a delicate fibrous tissue.

The *hepatic cells* are $\frac{1}{1000}$ to $\frac{1}{800}$ of an inch in diameter; they are polygonal and have one or two nuclei; their cell-body contains a granular protoplasm, albumin, oil-globules, glycogen, bile pigments, and salts. They are secreting cells and secrete from the blood the materials for the bile; they also possess the property of producing glycogen.

The *capillary plexus* of the portal vein contains the blood from which the hepatic cells principally derive the materials for their secretion. The *portal vein* is a short trunk which is formed by the union of the superior and inferior mesenteric and splenic and gastric veins. The portal vein enters the liver at its transverse fissure and there gives off separate branches to the lobes; these ramify and give off branches which pass between and around the lobules—these are called the *interlobular veins;* from these again branches are given off which pass into the lobule and form in it an *intralobular plexus;* in the middle of the lobule these capillaries open into a larger vein, which is called the *intralobular vein;* this passes out of the lobule and opens into a small vein at the base of the lobule, called the *sublobular* vein, from which the hepatic veins spring.

The *capillary plexus* of the hepatic artery supplies the nutrition for the structures of the lobules. The *hepatic artery* enters the liver at the transverse fissure together with the portal vein; in its course it gives off branches to the lobes and lobules; in the latter the artery breaks up into a capillary plexus, which finally, together with the capillary plexus of the portal vein, terminates in the sublobular vein.

The *bile-channels* are the beginning of the hepatic duct, by which the secretion of the liver is conveyed directly or indirectly to the intestinal canal. The *bile-channels* begin as minute spaces between the hepatic cells; the walls of the bile-channels are formed only by the adjacent sides of the hepatic cells. These minute channels radiate toward the periphery of the lobule, where they communicate with delicate vessels, the *interlobular bile-ducts;* these ramify between the lobules and gradually increase in diameter, until finally a main duct emerges from the structure of the left and one from that of the right portion of the liver. These *right* and *left hepatic ducts* then unite and form the *common hepatic duct.* The walls of these ducts are composed of fibrous tissue and contain non-striated muscular fibres. The ducts are lined with mucous membrane, which, in the smaller ducts, is covered with polygonal, and in the larger ducts with cylindrical, epithelial cells. The portal vein, the hepatic artery, and the hepatic ducts pursue the same course through the liver; they are contained in a fibrous sheath, which is called the *portal canal,* formed by a reflexion of the fibrous covering of the liver. A transverse section of the portal canal shows the openings of a portal vein, a hepatic artery, and a hepatic duct, which are distinguished by the characteristic structure of their walls.

The blood of the liver is conveyed into the *inferior vena cava* by the three hepatic veins. These begin at the capillary termination of the portal vein and hepatic artery, pursue independent courses through the substance of the

liver, and emerge at its posterior surface. The hepatic veins in their course are not found within the portal canals.

The liver is supplied with superficial and deep lymphatics.

The superficial lymphatics form a delicate network on the surface of the organ.

The deep lymphatics begin in the lobules; outside of these, lymph-ducts and vessels form, which ramify between the lobules and lobes, and in their course accompany the portal vein, hepatic artery, hepatic duct, and hepatic veins, and finally leave the organ with these.

The nerves of the liver are from the hepatic plexus, which is composed of fibres of the vagus and of the sympathetic. The nerves accompany, in their course through the liver, the ramifications of the hepatic artery. The nerves of the liver contain vasomotor and secretory fibres.

The functions of the *liver* are:

1. The *glycogenetic* function—namely, the property of producing glycogen. This function I will describe in detail when treating the subject of the elaboration and assimilation of the absorbed food materials.

2. The secretion of the bile.

Before describing the mode of the secretion of bile I will describe its physical properties and its chemical composition.

The *physical properties of bile* may be said to be as follows: *Bile* is a viscid, transparent fluid which has a yellow, sometimes a brown or dark-green color; its reaction is neutral; its specific gravity is 1020 to 1030. Bile is best obtained by means of a hepatic fistula, as that obtained from the gall-bladder is darker and more viscid.

The *chemical composition of bile* is as follows: water, 823 parts; solids, 177 parts.

The solid ingredients of the bile are:

1. The bile-salts and the bile-pigments.
2. Fat.

3. Cholesterin.
4. Mucus.
5. Inorganic salts and minerals.

The *specific ingredients of the bile* are the bile-salts and the bile-pigments. These do not pre-exist as such in the blood of the liver, but are formed from materials taken from the blood by the hepatic cells, and it is believed that these materials are furnished by the red blood-corpuscles, a great number of which undergo destruction in the liver; this is demonstrated by the decrease in the number of red blood-corpuscles in the blood of the hepatic veins, as compared with their number in the portal vein and hepatic artery. In the latter vessels the proportion of the white and red blood-corpuscles is 1 white to 740 red, while in the hepatic veins the proportion is 1 white to 170 red.

The *bile-salts* are the sodium glycocholate and sodium taurocholate. They are formed by the liver-cells from the albuminous material of the destroyed red blood-corpuscles; their formation is a chemical process, consisting in a dividing of the albuminous material into *taurin*, *glycin*, and *cholic* acid; these unite and form *taurocholic* and *glycocholic acids*, which unite with sodium to form the bile-salts named.

The bile-salts constitute about 9 per cent of the solid ingredients of the bile. In the human bile the sodium glycocholate preponderates. The difference in the two salts is that the sodium taurocholate contains sulphur.

The bile-salts are soluble in water, alcohol, and alkaline fluids, and can be precipitated from their solution in the form of colorless, needle-like crystals.

The chemical test generally employed to determine the presence of bile-salts is that prescribed by *Pettenkofer*. It is performed as follows: To the suspected solution are first added a few drops of a strong solution of sulphuric acid, and this is followed by the addition of a small quantity of a 10 per cent solution of cane-sugar; the result is the forma-

tion of a substance called *furfurol*, which in the presence of bile-salts assumes a bright-red or purple color, and it is this coloration of the suspected solution which indicates the presence of bile-salts.

The *bile-pigments* are *bilirubin* and *biliverdin.* They are formed by the hepatic cells from the hæmoglobin of the destroyed red blood-corpuscles.

It is believed that the bile-pigments are non-essential products which form during the formation of bile-salts. The bile-pigments do not partake in the action of the bile.

Bilirubin is obtained from the bile in the form of yellow, rectangular crystals which are soluble in water, alcohol, and chloroform.

Biliverdin is the green coloring matter of the bile; it is most abundant in the bile of the herbivora; it is formed from bilirubin as the result of oxidation.

Biliverdin is obtained from the bile in the form of an amorphous powder which is soluble in alcohol and in a solution of bile-salts, but insoluble in water.

In bile which has been retained for a time in the gall-bladder a third coloring matter is found, which is dark and is called *biliprasin;* it is formed by an oxidation of the biliverdin.

The chemical test generally employed for bile-pigments is that of *Gmelin.* Add to the suspected solution first a few drops of *nitric* and then a few drops of *nitrous* acid; if bile-pigments are present a number of colored rings appear, in the following order: green, blue, violet, red, and indigo; they indicate the degree of oxidation of the coloring matters.

Normally the bile-pigments are formed only in the liver; but in certain conditions—for instance, after the intravascular injection of a solution of bile-salts, after long chloroform narcosis, in fact in most pathological or other conditions in which a destruction of red blood-corpuscles takes place in the circulating blood—bile-pigments are formed in the blood.

In conditions where the flow of the bile from the liver is interfered with, owing to an obstruction of the bile-ducts, bile is absorbed by the blood. Whenever bile pigments exist in the blood their presence is indicated by a yellowish discoloration of the skin and of the sclerotic of the eye—a condition which is called *icterus* or *jaundice*. If the icterus is due to the *formation* of bile-pigments in the blood it is called *hæmatogenetic icterus;* if the icterus is due to the *absorption* of bile-pigments into the blood it is called *hepatogenetic icterus.*

The other ingredients of the bile—namely, the *cholesterin*, *lecithin*, *palmitin*, *olein*, and *stearin*, traces of *urea*, and a diastatic ferment of an unknown nature—pre-exist in the blood from which the bile is secreted. The inorganic ingredients of the bile—namely, the water and salts, principally sodium and potassium chloride, and the phosphates of calcium and magnesium—are also taken as such from the blood. The mucus contained in the bile is secreted by the epithelial cells of the mucous membrane lining the bile-ducts and gall-bladder.

Iron, which forms a constant ingredient of bile, is derived from the HO of the destroyed red blood-corpuscles in the liver. Bile also contains a small amount of gas, principally *oxygen*, *nitrogen*, and *carbon dioxide;* these are derived from the blood, into which they have been absorbed from the intestinal canal.

The question arises: From which kind of blood do the hepatic cells take the materials for their secretion, from that of the portal vein or from that of the hepatic artery?—both vessels forming a capillary plexus in the liver lobule.

Observations and experiments tend to show that it is principally the blood of the portal vein from which the cells derive their materials. The distribution of the branches of the hepatic artery indicates that this vessel is intended mainly for the nutrition of the structures of the liver.

If the hepatic artery is ligated the secretion of bile does

not cease, but gangrene of the liver occurs owing to insufficient nutrition of its structures.

Ligation of the portal vein causes death, through venous congestion of the abdominal viscera, so quickly that no observations as regards the effects of the ligation of that vessel on the hepatic secretion can be made. If through a pathological condition the portal circulation in a part of the liver is obliterated, a collateral circulation will soon be established.

If a branch of the portal vein supplying a lobe of the liver is ligated, the bile secretion in that lobe will be diminished, but not cease entirely, which fact tends to show that the hepatic artery also furnishes materials for the secretion of the bile.

Bile is secreted continually; during the period of intestinal digestion the bile is poured directly into the duodenum; during the interval the bile is stored in the gall-bladder.

The *gall bladder* is a membranous sac holding from 6 to 8 drachms; it is situated at the under-surface of the right lobe of the liver. Its duct, called the *cystic*, joins the *common hepatic duct* and forms one duct, which is called the *ductus communis choledochus;* this is about the size of a goose-quill, and opens into the posterior wall of the duodenum together with the pancreatic duct. The gall-bladder and its duct are lined with mucous membrane which is continuous with that lining the hepatic duct. The walls of the gall-bladder contain non-striated muscular fibres, which are arranged transversely and longitudinally; the introduction of food into the intestinal canal by reflex action causes a contraction of these muscular fibres, by which the bile stored in the gall-bladder is forced through the cystic duct and the ductus communis choledochus into the duodenum.

During the interval of digestion the opening of the ductus communis choledochus into the duodenum is closed, and, the flow of the bile not being sufficient to force an opening, the bile is forced back into the gall-bladder.

The quantity of bile secreted in twenty-four hours by the healthy human adult has been estimated to be from 700 to 900 grammes.

The secretion of bile is influenced by many conditions, which may be enumerated as follows:

1. The quality of food influences the secretion of the bile; it has been observed that it is increased when food rich in albuminous material is taken.

2. The blood-supply to the liver influences its secretion; it is for this reason that during the process of digestion, when the organs concerned in the process are congested, the secretion of bile is more abundant.

3. Nerves influence the secretion of bile; the termination of the nerve-fibres in the liver is not exactly known. Stimulation of the right pneumogastric below the diaphragm has no effect on the bile-secretion; section of the nerve at the same point also does not influence the activity of the liver; section or stimulation of the right pneumogastric above the diaphragm decreases or increases the flow of bile, but only as the result of the influence of such section or stimulation on the respiratory movements. Stimulation of the liver by electrical currents increases the flow of bile, but does so only by causing a contraction of the bile-ducts.

It may be said that all conditions which increase the blood-pressure in the liver also increase the secretion of bile, and *vice versa*.

The proper quality of the bile depends upon a normal activity of the hepatic cells and upon a proper condition of the blood and its ingredients.

LECTURE XVIII.

DIGESTION (*continued*).

The Bile.

THE actions and uses of the bile as a digestive juice may be enumerated as follows :

1. Bile assists in the emulsification of the fats in the intestinal canal. Bile when mixed with oil forms an emulsion. The fats are divided into fatty acids and glycerin by the action of pancreatic juice in the small intestines, and then form with the bile an emulsion in which fats are absorbable.

2. Bile prevents a continuation of the gastric digestion in the small intestines. The bile-salts, as they come in contact with the acidulous chyme which is conveyed into the small intestines, are separated by the action of the gastric juice. The glycocholic acid is precipitated by the gastric juice, and with it precipitates the pepsin. The albuminous and albuminoid ingredients of the chyme are precipitated by the taurocholic acid.

3. Bile aids in the absorption of the fats. Bile is a soapy fluid ; it moistens the mucous membrane of the small intestines and thus favors a transfusion of the emulsified fats.

4. Bile retards putrefaction of the intestinal contents, although bile itself undergoes a rapid decomposition when exposed to air.

5. Bile stimulates the muscular fibres of the intestinal canal and thus stimulates peristalsis and secretion.

6. The water of the freely secreted bile serves to give the soft consistence to the fæces.

7. Bile has a slight diastatic action, owing to the presence of a diastatic ferment.

The importance of bile as a digestive fluid is well demonstrated by the conditions which arise when the flow of the bile into the intestinal canal is interfered with. Incomplete intestinal digestion and constipation are the immediate results; the stools assume a clay color, owing to the presence of a great quantity of unabsorbed fat; the fæces are dry and hard, contain many undigested materials, and are characterized by a strong fetid odor. Constipation is due to the want of the stimulating effect of the bile on the muscular coat of the intestinal canal.

The studies and observations as to the final destination of bile-ingredients in the intestinal canal have led to the following conclusions:

1. The *water* is eliminated to the greatest extent with the fæces.

2. The *bile-salts* are reabsorbed in the intestinal canal; they are changed during their absorption, and they are not found as such in the blood; therefore it is believed that they serve further uses in the economy. Traces of them are excreted with the fæces and urine.

3. The *coloring matters* are to some extent reabsorbed in the intestinal canal, but undergo changes during this process; they are finally excreted by the kidneys as *urobilin*, the coloring matter of the urine.

A portion of the bile-pigments undergo a process of reduction and are eliminated as *stercobilin* and *hydrobilirubin*—two coloring matters of the fæces.

4. The *lecithin* and *cholesterin* contained in the bile are eliminated with the fæces.

5. The *inorganic salts* are to the greatest extent reabsorbed in the intestinal canal.

6. The *iron* is also, to some extent, reabsorbed; part of it is eliminated with the fæces.

7. The *mucus* is eliminated with the fæces.

In my last lecture I stated that bile is secreted continually. The flow of bile in the channels and ducts is maintained principally by the following factors:

1. By the continual activity of the hepatic cells.

2. By the mechanical pressure of the diaphragm upon the liver during the respiratory movements.

3. By the contraction of the muscular fibres contained in the walls of the larger bile-ducts.

A *résumé* of the digestive processes which take place in the intestinal canal as the result of the actions of the three digestive juices—viz., the pancreatic juice, the succus entericus, and the bile—upon the ingredients of the chyme may be given as follows:

1. The chyme, which, owing to the presence of the gastric juice, is acid, is rendered alkaline by the alkaline salts of the pancreatic juice.

2. The pepsin and albuminates are precipitated by the biliary acids.

3. Proteids are changed into peptones by the proteolytic ferments of the pancreatic and intestinal juices.

4. Fats are separated into fatty acids and glycerin by the action of steapsin.

5. Starches, dextrin, and other amylaceous ingredients are transformed into glucose by the diastatic ferments of the pancreatic juice, the bile, and the intestinal juice.

6. Fats are emulsified by the bile.

7. Cane-sugar, lactose, etc., are converted into dextrose by the action of invertin.

8. The intestinal contents are diluted by the water of the bile, succus entericus, and pancreatic juice.

From the foregoing it may be said that the intestinal digestion has for its purpose the continuation and completion of the digestion begun in the stomach.

Non-digested or indigestible ingredients of the food, together with certain excrementitious matters, are conveyed onward through the whole intestinal canal by the peristaltic contraction of its muscular fibres, and finally these substances are eliminated as the *fæces* by the act called *defecation*.

The time required for the passage of the intestinal contents through the whole intestinal canal is from 12 to 24 hours; during this period the following processes take place:

1. The digestion of unabsorbable materials, which takes place principally in the small, but to a limited extent also in the large intestines, as the result of the action of the secretions of the follicles of the latter.

2. The absorption of digested materials; this also takes place principally in the small intestines. The mucous membrane of the large intestines also takes up rapidly easily absorbable materials, such as water, saline solutions, etc.

3. Peristaltic motions, by which the food is mixed with the digestive juices, and by which the contents of the small intestines are conveyed onward in the intestinal canal.

4. Decomposition and putrefaction of ingredients of the intestinal contents, due to the presence of micro-organisms which are introduced into the alimentary canal with the food and drink, and which, by their growth and development, produce fermentation and putrefaction of the intestinal contents with the production of fetid gases and odors.

The micro-organisms existing in the intestinal canal may be divided as follows:

(*a*) According to their form:

Micrococci—round.
Vibrions—spiral.
Bacteria—rod-like, short.
Bacilli—rod-like, long.

(*b*) According to the changes they produce, into

1. Those causing fermentation:
   Bacterium lactis.
   Bacterium aceti.
   Bacterium butyricus.
2. Those causing the division of albuminous substances:
   Schizomycetes.

3. Those causing disease:
   Pathogenetic bacteria.
4. Those producing poisons in the intestinal canal:
   Toxigenetic bacteria.
5. Those producing coloring matters:
   Chromogenetic bacteria.
6. Those producing fetid odors:
   Bromogenetic bacteria.

The solid products of the decomposition of materials of the intestinal contents are *indol*, *skatol*, and *phenol*. They are organic nitrogenized, crystallizable substances formed during the decomposition of albuminous and albuminoid substances; they are constant ingredients of the fæces and give to them the characteristic fecal odor.

The gases produced as the result of the decomposition of ingredients of the intestinal contents are: carbon dioxide (CO_2), sulphuretted hydrogen (H_2S), carburetted hydrogen (CH_4), and hydrogen (H).

The formation of the fæces takes place principally in the large intestines. The intestinal contents, as they pass onward toward the large intestines, assume a fetid odor, and often an acid reaction owing to the formation of acids as the products of putrefaction and decomposition.

In the beginning the fecal matter is soft and semi-liquid, but as it passes on and reaches the lower portion of the large intestines it is of a more solid consistence, so that a mass forms which assumes the shape of the interior of the bowel. The firm consistence of the fecal masses in the lower part of the large intestines is due to the fact that during their passage through to the large intestines water and soluble ingredients are absorbed from them, and to the fact that the property of absorption of the mucous membrane of the large intestines is greater than its property of secretion.

The digestive juice secreted by the follicles of the mucous membrane of the large intestines is scanty and very tenacious, owing to the great quantity of mucus it contains.

The quantity of fecal matter formed in twenty-four hours varies with the quantity and quality of food taken. Ordinarily it is from 150 to 250 grammes; it is greater when vegetable foods are taken than it is when meat constitutes the principal ingredient of the food. The composition of the fæces also varies with the character of the food taken. Normally it is composed of water 70 to 80 per cent, solids 20 to 30 per cent.

The solids are: 1. Indigestible ingredients of the food, such as cellulose, cartilage, elastic fibres, fibres from vegetables, etc.

2. Non-digested ingredients of the food which, owing to their preparation or insufficient mastication, were incompletely digested or not digested at all during their passage through the alimentary canal.

3. Salts which are not easily absorbed, or which with others form insoluble compounds—phosphates of calcium and magnesium, small portions of iron, etc.

4. Decomposition products of albuminous or albuminoid substances—indol, skatol, phenol.

5. Mucus.

6. Products of the decomposition of the specific bile-ingredients in the intestinal canal—stercobilin and hydrobilirubin, formed from the bile-pigments; traces of biliary acids.

7. Cholesterin and lecithin from the bile.

8. Fat, when such has been taken in excess with the food.

9. Acids which are formed during decomposition and fermentation in the intestinal canal, such as lactic acid, butyric acid, etc.

10. Gases—CO_2, NH_4, H_2S, CH_4, and H.

11. Bacteria.

7. *Defecation.*

Defecation is the act by which the fæces are eliminated from the intestinal canal. The contents of the intestines pass through the small intestines in about three hours,

and then in about twelve hours through the large intestines. The intestinal contents are moved onward by the peristaltic contractions of the muscular fibres.

The peristaltic action of the small intestines is more active than that of the large.

The lower part of the rectum is guarded by two muscles, called the *internal* and the *external sphincter ani;* the first is an involuntary, and the second a voluntary muscle.

The act of defecation is a reflex, but also a voluntary nervous act. The collection of fæces in the lower part of the rectum produces, by its irritating effect on the sensory nerve-fibres of the mucous membrane of the rectum, the desire to defecate; the stimulus is conveyed to the brain and to the *centre of defecation*, which is located in the spinal cord in the lumbar region. The response to the stimulus is a relaxation of the sphincter ani internus. By contracting the external sphincter ani the escape of fæces can be prevented for a time, until the strain to which that muscle is subjected by the constant pressure of the fæces from within is too great and overcomes the voluntary contraction of the muscle, and an involuntary escape of the fæces is the result. Immediately after the act of defecation the sphincters contract for a while. As long as there are no fæces in the rectum the sphincters are not contracted, but the elasticity of the soft parts surrounding the lower portion of the rectum and its external opening, the anus, is sufficient to close the latter.

The centripetal or sensory nerves for the act of defecation are from the hemorrhoidal and from the inferior mesenteric plexus.

The contrifugal or motor nerves are from the pudic plexus and are distributed to the sphincters.

When the act of defecation is performed by an effort of the will the external sphincter is relaxed, and the muscles of the abdominal walls are contracted to aid by their pressure in the expulsion of the fæces.

QUESTIONS AND EXERCISES.

SUBJECT.—*Digestion.*

Lectures XII.–XVIII. inclusive.

252. What is meant by digestion?

253. Name the organs composing the digestive apparatus.

254. Name the stages of digestion.

255. Name the mechanical processes of digestion.

256. Name the chemical processes of digestion.

257. Name the various portions of the alimentary canal.

258. Name the digestive juices.

259. Describe the act of prehension.

260. Name the number of permanent and temporary teeth in the human being.

261. Give the periods of eruption of the temporary and the permanent teeth.

262. When does the development of the temporary and when does that of the permanent teeth begin?

263. Describe the process of the development of the temporary teeth.

264. Describe the process of the development of the permanent teeth.

265. What causes the shedding of the temporary teeth?

266. What is the difference in the form of the human teeth and those of the carnivora and those of the herbivora?

267. Why is the alveolar process of the jaws not repaired, like all other bony tissues, after fracture, etc.?

268. What is the percentage of animal and of earthy matter in enamel, dentin, cementum?

269. What is pericementum?

270. Name and describe the motions by which mastication is effected.

271. Name the muscles which produce the motions required for mastication, and describe their action.

272. Describe the nervous mechanism of the act of mastication.

273. What is the function of the dental periosteum?

274. Describe the formation of dentin and enamel.

275. Draw a vertical section of a tooth, indicating by name the various parts. Describe each part.

276. At what period of life is the development of teeth first indicated?

277. Define calcification.

278. Give the process of replacement of temporary by permanent teeth.

279. Name the glands of the mouth. How are they classified?

280. Name the salivary glands. To what class of glands do they belong, according to their structure?

281. Describe the anatomy and structure of the parotid glands, their blood and nerve supply, their minute structure, and the quality of their secretion.

282. Give the anatomy and minute structure of the submaxillary glands, and describe the quality of their secretion.

283. Give the anatomy and minute structure of the sublingual glands, and describe the quality of their secretion.

284. Name and describe the ducts of the salivary glands.

285. Give the composition of human saliva.

286. Describe the mode of secretion of saliva.

287. What are the properties of saliva?

288. What is the effect of saliva on starch?

289. What are the reaction and specific gravity of saliva? How is this reaction tested?

290. What would be the effect on the saliva and on digestion if Stenson's duct were divided?

291. Describe the nervous mechanism of the secretion of saliva.

292. What is the average quantity of saliva secreted in twenty-four hours by the healthy human adult?

293. What drugs increase and what drugs decrease the flow of saliva?

294. Name the ferment of the saliva. Describe its action.

295. Name the organs concerned in the act of deglutition.

296. Name the muscles which form the tongue.

297. Name the muscles of the soft palate.

298. Describe the pharynx.

299. With what cavities does the pharynx communicate?

300. Describe the œsophagus.

301. Through what opening in the diaphragm does the œsophagus pass?

302. Describe the epithelial covering of the mucous membrane lining the buccal, pharyngeal, and œsophageal cavities.

303. Describe the stages of deglutition.

304. How is the food prevented from entering the laryngeal cavity and the upper respiratory passages during the act of deglutition?

305. Describe the nervous mechanism of the act of deglutition.

306. What is the stomach, and where is it located?

307. Give the relations of the stomach to the viscera surrounding it.

308. Describe the measurements, shape, opening, and the various anatomical points of the stomach.

309. Name the nerves and blood-vessels supplying the stomach.

310. Name the coats composing the walls of the stomach.

311. Describe the arrangement of the muscular fibres of the stomach.

312. Describe the structure of the mucous coat of the stomach.

313. Describe the glands of the stomach.

314. Describe the motions of the stomach.

315. Give the reaction, specific gravity, and composition of the gastric juice.

316. Name the specific ingredients of the gastric juice.

317. What is pepsin, and how can it be obtained from gastric juice?

318. Where and how is pepsin found?

319. In what does pepsin differ from the proteolytic ferments?

320. Where and how is HCl of the gastric juice formed?

321. What is the quantity of free HCl in the gastric juice?

322. What are the properties and functions of the gastric juice?

323. Describe the mode of secretion of gastric juice, and the approximate quantity ordinarily secreted by a healthy human adult in twenty-four hours.

324. What is the effect of alcohol on the gastric digestion? What is the average duration of gastric digestion?

325. What is the chyme? Describe its composition.

326. What is the effect of gastric juice upon cooked meats, fried or broiled meats, raw, soft, and hard-boiled eggs, bread, adipose tissue, bone, cartilage, elastic tissue, fat, sugar, starches, and vegetables?

327. Describe the physiology of vomiting.

328. Name the digestive juices which are poured into the small intestines.

329. Give the names of the various portions of the small and the large intestines.

330. Give the coats which form the walls of the intestinal canal.

331. Describe the arrangement of the muscular fibres in the walls of the small and the large intestines.

332. Describe the mucous membrane of the small intestines.

333. What are the villi? Where are they found?

334. What are solitary glands, and agminate glands or Peyer's patches, and where are they found?

335. Name and describe the secreting glands of the intestinal canal.

336. Give the nerve and blood supply to the intestines.

337. Give the reaction, specific gravity, and composition of the succus entericus.

338. Name the digestive properties of the succus entericus.

339. Describe the pancreas.

340. Give the specific gravity and reaction of pancreatic juice.

341. Give the composition of pancreatic juice.

342. Name the ferments of the pancreatic juice and their actions.

343. Describe the mode of secretion of pancreatic juice.

344. Give a *résumé* of pancreatic digestion.

345. At what point does the duct of the pancreas open into the intestinal canal?

346. Where is the bile secreted?

347. Name the fissures, lobes, ligaments, and coverings of the liver, and give the average weight and measurements of that organ.

348. What is Glisson's capsule?

349. Describe the liver lobule and the structural elements composing it.

350. Describe the portal circulation.

351. Describe the course of the hepatic artery and that of the hepatic veins.

352. Describe a hepatic cell and give its composition.

353. Describe the course of the bile-ducts.

354. Name the structures contained in a portal canal.

355. Give the specific gravity, reaction, and color of human bile.

356. What is the average quantity of bile secreted by man in twenty-four hours?

357. Give the composition of the bile.

358. Name and describe the specific ingredients of the bile.

359. Give Pettenkofer's test for bile-salts.

360. Give Gmelin's test for bile-pigments.

361. How are the ingredients of the bile formed in the liver? Explain. Give reasons to substantiate your statement.

362. Name conditions which influence the secretion of the bile.

363. Describe the mode of the secretion of the bile, and state its course to the intestinal canal.

364. Name conditions influencing the flow of bile.

365. What are the uses of bile? Describe in detail.

366. What is the final destination of bile in the intestinal canal?

367. What is icterus?

368. What is hæmogenetic and what is hepatogenetic icterus?

369. Name some conditions resulting from obstruction of the bile-ducts.

370. Give a *résumé* of the digestive processes in the intestinal canal.

371. Discuss bacteria in the intestines.

372. Describe the peristaltic movements of the intestines.

373. Describe the digestive changes in the large intestines.

374. What would be the effect on the intestinal digestion if the pancreatic duct were obstructed?

375. What conditions favor gastric digestion?

376. Describe the digestion in the stomach of a meal of bread and milk.

377. Name the ferments that are essential constituents of each digestive fluid.

378. Describe the digestion of a meal of eggs and beef.

379. Give the composition of normal fæces.

380. State the average weight of the fæces in twenty-four hours in a normal condition of health. What proportion is made up of liquid and what of solid ingredients?

381. How do bacteria get into the intestinal canal, and what is the result of their presence there?

382. Name the gases developed in the intestinal canal.

383. What are indol, skatol, phenol, stercobilin, hydrobilirubin? How and from what are they formed in the intestinal canal?

384. What is the time required for the passage of the intestinal contents through (*a*) the small intestines, (*b*) the large intestines?

385. Describe the nervous mechanism of the act of defecation.

LECTURE XIX.

ABSORPTION.

By the term *absorption* is meant the introduction of materials into the circulation. Absorption takes place to a greater or less extent from all parts of the body, from the free surfaces—viz., the mucous, serous, and synovial membranes, and the skin—and from the interstices of the tissues.

Absorption from the surfaces has for its main object the taking into the circulation of the materials intended for the nutrition of the tissues; it takes place principally from the mucous membrane of the alimentary canal. Absorption from the surfaces often plays an important *rôle* in the repair of pathological conditions; in acute inflammatory diseases—for instance, in acute articular rheumatism, pleurisy, peritonitis, meningitis, pericarditis, etc.—there is often an effusion of fluid into the affected serous or synovial cavities. This fluid is at times completely resorbed by the membrane forming the walls of the cavity.

Absorption from the interstices of the organs and tissues has for its object the draining of the superfluous parenchymatous fluid. The tissue elements receive their nutritive materials through the blood; its plasma, holding in solution the required nutritive materials, exudes through the walls of the capillaries into the interstices of the tissues and constitutes the *parenchymatous fluid;* the tissue elements take from it the materials they require and give into it their waste materials; the parenchymatous fluid is then absorbed and returned into the blood circulation. Absorption from the interstices is very active, and this fact is used extensively in the administration of medicines. I refer

here to the hypodermic and parenchymatous injections when a rapid effect of the drug employed is desired. Absorption from the surfaces is most active from the mucous membrane. The skin, owing to the kind and arrangement of its many layers of epithelial cells, possesses a very limited property of absorption.

The absorption of the nutritive materials which are con tained in the food and drink takes place from the surface of the mucous membrane of the alimentary canal.

The food contains absorbable and non-absorbable nutritive materials; the latter are made absorbable in the alimentary canal by the process of digestion. The absorption in the alimentary canal begins in the mouth, but is more active in those portions of the canal below the diaphragm, viz., in the stomach and intestines; it is most active in the small intestines.

The structure of the mucous membrane of the small intestine renders it particularly well adapted for absorption. Let me refer to the following points: 1. The mucous membrane of the small intestines is arranged in transverse folds, the valvular conniventes; these form incomplete circular projections into the lumen of the intestinal canal; by this arrangement the mucous membrane presents a larger surface for absorption, and a too rapid passage of the contents through the intestines is prevented. 2. The mucous membrane of the small intestines, like that of the whole alimentary canal below the cardiac opening of the stomach, is covered with a single layer of cylindrical epithelium, beneath which the capillaries ramify. 3. The mucous membrane of the small intestines presents numerous minute, cone-like elevations called villi; they give to the mucous membrane of the small intestines a velvety appearance. The structure of the villi makes them special organs of absorption.

A villus is conical in shape, from 3 to 5 millimetres long, and has the following structure: In the centre there is a

longitudinal, delicate vessel, beginning in a pouch-like expansion near the apex of the villus, and communicating at the base with the delicate lymph-channels beneath the epithelial layer; this delicate vessel is called the *lacteal.* The lacteals are the beginnings of the lymphatics of the small intestines. The lacteal is surrounded by a layer of non-striated *muscular fibres;* outside of this is a network of areolar and adenoid tissue which contains numerous large lymphoid cells in its meshes. This areolar and adenoid network forms the matrix of the villus; it supports a plexus of capillary nerve-fibrillæ and the lacteal. The external covering of the villus consists of delicate basement membrane covered with a single layer of cylindrical epithelial cells; the free border of these cells presents a striated appearance and is called the *striated basilar border.* The villus receives blood by a delicate arteriole which enters the villus at one side of its base; the blood is carried off by a veinule which leaves the villus at its base opposite the point where the arteriole enters; in the matrix of the villus the blood-vessels form a capillary plexus.

The absorption of materials into the circulation takes place through the walls of the blood- and lymph-capillaries. The materials absorbed into the blood-capillaries are conveyed by the blood-circulatory system to their point of destination. The materials absorbed into the lymph-capillaries are carried by the lymph-vessels through lymphatic glands, and are finally emptied into the blood-circulatory system. The blood-circulatory system consists of the heart, arteries, capillaries, and veins.

The *blood-capillaries* are freely distributed through the tissues and organs; their walls consist of a single layer of large, nucleated, polygonal endothelial cells continuous with the endothelial lining of the arteries and veins.

The capillaries anastomose between the structural elements of the tissues. The blood-capillaries of the stomach and intestinal canal are located beneath the epithelial layer.

The blood of the stomach and intestinal canal, which contains the materials absorbed into the capillaries in these locations, is conveyed by the gastric, splenic, the superior mesenteric, and the inferior mesenteric veins into the portal vein, by which it is carried into the liver.

The lymphatic system consists of lymph-capillaries, lymph-vessels, and lymphatic glands. The *lymph-capillaries* are delicate vessels, the walls of which are composed of a thin, fibrous membrane lined with a single layer of endothelial cells. The lymph-capillaries begin in various ways: 1. From *lymph-spaces*, which are small lacunar openings or cavities contained in the connective tissues. 2. From *perivascular spaces*, which are situated between the delicate capillary blood-vessels in the nerve-centres, bone-tissue, etc. 3. From *stomata*, which are small, angular spaces between the epithelial cells covering the walls of the serous and synovial cavities. 4. From the *lacteals*, which are the beginnings of the lymph-capillaries of the small intestines.

The lymphatic vessels convey the material taken by the lymph-capillaries through the lymphatic glands into the blood circulation. The lymph-vessels, like the blood-vessels, have a varying calibre. Their walls are composed of three coats—namely, an external coat, which is composed of areolar tissue and non-striated muscular fibres; a middle coat, composed of muscular and elastic fibres; and an internal coat, composed of a single layer of polygonal endothelial cells. The interior of many lymph-vessels is provided with valves, which are reduplications of the endothelial lining and are intended to prevent a regurgitation of the lymph. They are most abundant near the glands.

The *lymphatic glands* are small, oval masses of adenoid tissue interposed in the course of the lymph-vessels. Lymphatic glands are found in the vicinity of the large abdominal and thoracic vessels, and in the regions of the neck, axilla, elbow, in the groin, and in the popliteal space.

The solitary or Peyer's glands contained in the submucosa of the intestinal canal, and the glands of the mesenteric, are also lymphatic glands. A lymphatic gland consists of a convex and a concave portion; the latter is termed the *hilus*. The whole gland is covered with a *capsule* composed of fibrous tissue and non-striated muscular fibres; from this capsule prolongations are sent into the substance of the gland, dividing it into compartments or *alveoli;* these fibrous structures constitute the *cortical* portion of the gland. The alveoli are filled with adenoid tissue containing lymph-corpuscles; these structures constitute the *medullary* portion of the gland. The lymphatic vessels enter at the cortical portion; their contents pass through the network of the medullary portion, and finally leave the gland by a vessel which passes out at the hilus. The contents of the lymphatics, called the *lymph*, are conveyed into the blood-circulatory system. The lymph from the lower part of the body—namely, from the lower extremities, the pelvis and pelvic viscera, the abdomen and abdominal viscera—also the lymph from the small intestines, is collected in the *receptaculum chyli*. This is a triangular pouch situated in the abdominal cavity in front of the second lumbar vertebra; its coats are composed of fibrous tissue containing elastic and non-striated muscular fibres; from this the lymph is conveyed by a vessel, the *thoracic duct*, into the blood circulation.

The *thoracic duct* is a lymph-vessel, about 18 inches long, which passes through the aortic opening in the diaphragm, ascends into the posterior mediastinum of the thoracic cavity, and finally opens into the subclavian vein at its junction with the left internal jugular vein. The thoracic duct is supplied with numerous valves; during its course through the thoracic cavity it receives the lymph from the thoracic viscera.

The lymph of the right upper part of the body is conveyed by a short duct, the *right lymphatic duct*, into the

venous circulation ; it opens into the right subclavian vein at the point of junction of that vessel with the right internal jugular vein. The fluid circulating in the lymphatic system is called the *lymph.*

The physical properties and composition of lymph are as follows : Lymph is a colorless alkaline fluid, which has no odor, a saline taste, and a specific gravity of 1012 to 1020. Lymph is composed of lymph-plasma and lymph-corpuscles.

Lymph-plasma is identical with blood-plasma; it is composed of water, inorganic salts, serum-albumin, and alkaline-albumin ; it also contains fibrin-forming substances which cause lymph to coagulate slowly into a jelly-like mass when exposed to air. Lymph-plasma is the fluid which exudes through the walls of the capillaries into the interstices of the tissues.

Lymph-corpuscles are large, nucleated, spherical cells identical with leucocytes. They originate in the lymphatic glands and in the organs which in this structure contain adenoid tissue. This is shown by the fact that the lymph-capillaries do not contain lymph-corpuscles, and that the lymph in a vessel leaving a lymphatic gland contains a greater number of lymph-corpuscles than the lymph in the vessel entering the gland.

The physiological functions of the lymph-corpuscles were described in the remarks on the leucocytes.

The lymph contained in the lymphatics of the small intestines is called the *chyle*, from the milky appearance which it assumes by its mixture with the fat which is absorbed by the lacteals in the small intestines. Chyle, therefore, is lymph plus fat.

The factors which maintain the circulation of the lymph are the following :

1. The force exerted from behind by the materials which are constantly taken up by the lymph-capillaries.

2. The contraction of the muscular fibres of the walls of the lymphatic vessels.

3. The contraction of voluntary muscles.
4. The respiratory movements.
5. Nerve influence.
6. The valves in the interior of the lymph-vessels which prevent a regurgitation of the lymph.

The amount of lymph circulating in the system, and the amount of lymph which is poured into the blood circulation in twenty-four hours, has been estimated to be equal to the amount of blood in the body. The rapidity of the circulation is very much slower than that of the blood.

The lymphatic glands are, as I have stated before, the organs in which lymph-corpuscles originate; they are formed as the product of the elaboration of materials by the glands. The lymphatic glands serve another very important purpose: through them the lymph is filtered in its course to the blood circulation, and materials are often retained the introduction of which into the blood circulation would be the cause of disease. Poisons, pathogenic substances, and bacteria are often absorbed by the lymphatics and retained in the lymphatic glands, as is shown by their enlargement in many infections—for example, in syphilitic and tubercular infections.

LECTURE XX.

ABSORPTION (*continued*).

THE absorption of nutritive materials takes place in the alimentary canal through the walls of the delicate blood- and lymph-vessels.

As the factors which effect the absorption, must be considered, first, the special physiological function of the epithelial lining of the alimentary canal, and, second, physical forces—viz., diffusion, endosmosis, and filtration.

The *diffusion* of liquids is a physical process, consisting in the tendency of two or more liquids contained in a vessel to mingle until an equal mixture of the liquids in the vessel has taken place. The diffusion of liquids takes place independent of their specific weights and pressure. A diffusion can occur only between liquids which are capable of forming a mixture; it is for this reason impossible between two liquids like oil and water.

Endosmosis is a physical process which consists in the tendency of the particles of two or more liquids contained in a vessel and separated by a porous membrane to mix through the pores of the animal membrane until an equal mixture of the liquids has taken place.

Endosmosis takes place only between liquids which are capable of a mixture; it takes place independent of any pressure and independent of the specific gravity of the liquids. During the endosmosis of liquids an exchange of all substances occurs which are dissolved in the liquids and which readily pass through animal membrane; such substances are termed *crystalloids*, in contradistinction to substances which do not readily pass through the

pores of animal membranes and which are called *colloids.*

The endosmotic current is not always the same between the particles of different liquids, but it depends upon the nature of the liquids and the diffusibility of the substances contained in them. The rule is that the current always flows from that side of the animal membrane where the liquid is more easily diffusible to that side of the membrane where the liquid is less easily diffusible. By *diffusibility* is meant the power of a liquid to pass through the pores of an animal membrane.

The diffusibility of a liquid depends largely upon the character of the substances contained in it. It may be said that the absorption of the nutritive materials in the alimentary canal is due to a great extent to an endosmosis between the liquid contained in the intestinal tract and that contained in the lymph- and blood-vessels, the walls of which form the animal membrane through which the endosmosis takes place.

The direction of the current is from the intestinal canal into the lymph- and blood-vessels, because ordinarily the liquid in the alimentary canal passes through the animal membrane more readily than the liquid contained within these vessels. The most important factor of this direction of the current must be considered the special physiological property of the epithelial cells covering the mucous membrane of the alimentary canal.

Another important point in the absorption of substances is their endosmotic equivalent. It has been observed that substances contained in the liquids separated by an animal membrane are often exchanged during the endosmotic current for a certain quantity of water from the side toward which they diffuse.

The quantity or weight of water which, during the endosmotic process, is exchanged from the liquid on the one side of the animal membrane for one gramme of a sub-

stance contained in the liquid on the other side of the animal membrane, is called the *endosmotic equivalent* of that substance. For example, the endosmotic equivalent of sodium chloride is 4. To illustrate this we will take a vessel which contains two liquids separated by an animal membrane, one of which is distilled water, the other a solution of sodium chloride. During the endosmotic process through the animal membrane 4 cubic centimetres of distilled water will pass toward the sodium chloride solution for each gramme of this salt which passes from its solution toward the distilled water on the other side of the animal membrane. Ordinarily the substances which we take with the food and drink do not possess a higher endosmotic equivalent than the substances contained in the fluid in the lymph- and blood-vessels into which they are absorbed, and consequently during their absorption no water passes from the blood- and lymph-vessels into the fluid contents of the alimentary canal.

When substances are introduced into the alimentary canal which have a high endosmotic equivalent their absorption then causes a watery effusion into the alimentary canal, and watery diarrhœa is the result. Substances given for this purpose are: sulphate of magnesium, which has an endosmotic equivalent of 12; sulphate of sodium and potassium, having an endosmotic equivalent of from 11 to 12. Sugar, which has an endosmotic equivalent of 7, also causes watery diarrhœa when taken in large quantities.

The endosmotic equivalent of substances is not always the same; it is, for instance, increased when the substance is well diluted, and decreased when the substance is in a concentrated solution; it increases as the temperature of the solution is increased. The character of the animal membrane through which the endosmosis takes place also influences the endosmotic equivalent of the substances contained in solution.

The *filtration* of liquids is a physical process which consists in the passing of the liquids through the pores of an animal membrane when subjected to pressure.

Filtration depends upon the amount of pressure upon the liquid; upon the character of the liquid and the substances contained in it; upon the degree of concentration of the solution; and, lastly, upon the character of the membrane through which the fluid is filtered, and upon the temperature of the liquid to be filtered.

The filtration of liquids is more active when the animal membrane is porous, when the liquid has a good affinity for the membrane, when the substances contained in the liquid pass readily through the pores of the animal membrane, when the solution of the substances is diluted, and when the temperature of the liquid is raised. Colloids contained in liquids to be filtered do not pass through the pores of animal membranes; filtration is for this reason employed to separate the colloids from the crystalloids contained in a solution.

The introduction of substances into the circulation by the process of filtration takes place in the alimentary canal when its muscular walls contract and thus exert a pressure upon the intestinal contents.

From the foregoing description of the processes which effect absorption it can be clearly understood that the absorption of substances depends upon various conditions, which may be enumerated as follows:

1. Upon the diffusibility of the substances. The more readily substances pass through an animal membrane, the quicker they are absorbed; colloid substances are not absorbed.

2. Upon the density of the liquid and the grade of concentration of the solution. The less concentrated a solution is, the quicker it is absorbed.

3. Upon the condition of the animal membrane through which the substances are absorbed.

4. Upon the tension of the vessels into which the substances are absorbed. By the *tension* of the vessels is meant the pressure which the fluid contained in them exerts against the walls. The greater the tension the less rapidly substances are absorbed.

5. Upon the rapidity of the circulation of the fluids contained in the vessels into which substances are absorbed. The circulation carries away the fluid and the absorbed materials contained in it, and consequently the fluid is constantly renewed for the reception of materials; therefore the more rapid the circulation the quicker the absorption.

6. Upon the temperature of the liquids to be absorbed, and upon the endosmotic equivalents of the substances. The absorbability of liquids increases with an increase in their temperature.

Substances having a high endosmotic equivalent are best absorbed from well-diluted solutions.

The absorption of the nutritive materials which are taken with the food and drink takes place, as I have stated, from the mucous surface in all parts of the alimentary canal. It begins in the mouth to a very limited extent, owing to the stratified epithelial covering of the mucous membrane of the buccal cavity; it is negative in the pharynx and œsophagus, owing to the rapidity with which the food passes through these portions of the alimentary canal; it is more active in the stomach, most active in the small intestines, and again less active in the large intestines.

The materials in the alimentary canal are absorbed by the blood- and lymph-vessels.

Water is absorbed principally by the blood-vessels; a small amount of it passes into the lymphatics. Water is absorbed quickly and completely.

The *salts* are also absorbed by the blood-vessels, and, to a small extent, probably by the lymphatics. Salts are readily absorbed only when in a weak solution; too concentrated

solutions of salts cause an effusion of water from the vessels into the intestinal canal. Sodium chloride, the salt which we take most frequently, is readily absorbed as long as it is in a solution not exceeding 2 per cent.

The *carbohydrates* are transformed, by the process of digestion, into sugars which readily pass through animal membranes. *Sugars* are absorbed into the blood-vessels, very little by the lymphatics. Sugars having high endosmotic equivalents are therefore readily absorbed only when in a weak solution.

The *albuminous* substances are transformed into peptones; these, in the slightly acid or alkaline liquid of the stomach and intestinal contents, are readily absorbed. Peptones have a high endosmotic equivalent, and are therefore only absorbed from a dilute solution, to obtain which a certain quantity of fluid must be taken with the food. The *peptones* are absorbed by the blood-vessels. Proteids are colloids and are therefore not absorbed.

The *fats* which are taken with the food are prepared for absorption in the small intestines. The liberated fat- or oil-globules are here split up by the steapsin of the pancreatic juice into fatty acids and glycerin; these mix with water and alkaline salts from the intestinal juices, and soap is thus formed; this, with the bile, forms an emulsion, in which are contained the exceedingly finely divided fat- and oil-globules, which now pass into the lacteals and are thus taken up into the lymph circulation.

The method by which the fats pass into the lacteals is not fully understood. It has been observed that during the process of absorption minute fat-globules are contained in the epithelial cells covering the villi, and it is believed that the striæ of the basilar border of the epithelial cells grasp the fat-globules, and that these are passed through these cells by a protoplasmic movement. It has furthermore been observed that the large lymphoid corpuscles which are contained in the adenoid tissue of the matrix of

the villi send out prolongations from their bodies, which pass between the epithelial cells covering the villi and grasp the fat-globules and convey them into the lacteals; from these they are forced, by the contraction of the muscular fibres surrounding each lacteal, into the lymph-channels in the walls of the small intestines, where they, together with the lymph, constitute a milky fluid—the *chyle.* The fats are absorbed only by the lacteals of the small intestines.

Absorption from the large intestines is less effective; the most nutritive materials are already absorbed in the small intestines. Water, and easily absorbable substances dissolved in water, are readily absorbed in the large intestines. The contents of the small intestine, as they pass into the large intestine, are quite liquid, but become more and more solid as they descend in the large intestine, owing to the absorption of the water in this part of the alimentary canal. In pathological conditions where feeding by the mouth is impossible, easily absorbable nutritive materials are brought by means of *rectal injections* into the large intestines, where they are subjected to the action of the digestive juice secreted by the follicles of the mucous membrane of the large intestines, and where they are readily absorbed. *Rectal medication* is also based upon the comparatively great absorbing power of the mucous membrane of the large intestines.

QUESTIONS AND EXERCISES.

SUBJECT.—*Absorption.*
Lectures XIX. and XX.

386. What is meant by the term absorption ?

387. What structures make up the blood-circulatory system ?

388. Describe the structure of a blood-capillary.

389. What structures make up the lymphatic system?

390. Describe a lymph-capillary.

391. Name the various ways in which lymph-capillaries begin.

392. Describe the structure of a lymphatic vessel.

393. Describe the structure of a lymphatic gland.

394. What is adenoid tissue?

395. Give the direction of the current in the lymph-circulatory system.

396. Trace the course of the lymph from the various parts of the body into the blood circulation.

397. Name the factors which maintain the circulation of the lymph.

398. Give the properties and composition of the human lymph.

399. Describe a lymph-corpuscle.

400. Where do the lymph-corpuscles originate? Give reasons to substantiate your statement.

401. Where are the constituents of the lymph derived from?

402. How do the tissue elements receive their nutrition from the blood?

403. What is the parenchymatous fluid of the tissues and organs?

404. What is chyle, and where is it found?

405. Trace the course of the chyle into the blood.

406. Why does the skin possess but little absorbing power?

407. Describe the structure and distribution of the mucous, serous, and synovial membranes.

408. Why is absorption more active in the parts of the alimentary canal below the diaphragm than in those above?

409. Why is absorption from the small intestines more active than from the stomach?

410. Describe the structure of the mucous membrane of the small intestines.

411. Describe the structure of a villus.

412. What is a lacteal?

413. Describe where and by what the water, the inorganic salts, the carbohydrates, and the peptones are absorbed.

414. Describe how the fats are absorbed by the lacteals.

415. What do you understand by hypodermic injections, parenchymatous injections, rectal medication, rectal feeding?

416. Discuss the absorbing power of the large intestines.

417. What do you understand by the diffusion of liquids?

418. What is endosmosis?

419. What is filtration?

420. In what direction is the endosmotic current between two liquids separated by an animal membrane?

421. Why is the endosmotic current from the intestinal canal into the lymph- and blood-vessels?

422. What do you understand by the endosmotic equivalent of a substance?

423. How does the degree of concentration and the temperature affect the absorbability of substances?

424. What are colloid and what are crystalloid substances?

425. Enumerate and describe the conditions which influence and regulate absorption.

426. What are the channels of absorption?

427. Discuss the physiology of rectal feeding.

428. State the difference between lymph and chyle.

429. What are the functions of the lymphatic glands?

430. How do the products of digestion enter the circulation?

431. Describe the physiologic process by which the bite of a venomous snake, or a hypodermic injection of the virus, causes death.

432. Describe the process of absorption of a meal consisting of bread and butter and ham, and mention the digestive changes which these articles of food must first undergo.

433. How does the circulation of the lymph and blood influence absorption? Explain.

LECTURE XXI.

BLOOD CIRCULATION.

The blood circulation has for its object the conveying of nutritive material to the tissues, the carrying of the waste materials from the tissues, and the distributing of warmth to the different parts of the body. The blood circulates in the blood-circulatory system, which consists of the heart, the arteries, the capillaries, and the veins.

To understand the circulation of the blood it is essential to be thoroughly familiar with the structure of the organs composing the blood-circulatory system. I will therefore describe the structure of these organs.

The Heart.

The heart is a hollow, muscular organ situated in the thoracic cavity between the lungs and behind the lower portion of the sternum. It is conical in shape, with its base directed upward, backward, and to the right. The surface of the heart which is directed toward the anterior chest wall is convex, and formed principally by the walls of the right ventricle, also by a small portion of the anterior wall of the left ventricle. The surface directed posteriorly is flattened and rests partly on the diaphragm; it is formed principally by the walls of the left ventricle.

The base of the heart corresponds to the space between the fifth and eighth dorsal vertebræ; the apex, to a point in the fifth intercostal space three-fourths of an inch to the left of the sternum and an inch below the left nipple.

The heart is contained in a closed membranous sac, the

pericardium, which consists of an *outer* fibrous and an *inner* serous layer; the latter covers the entire surface of the heart, and, being reflected, forms the lining of the whole pericardial cavity.

The pericardium is attached above to the large vessels; below, to the central tendon of the diaphragm. The function of the pericardium is the prevention of friction and the facilitation of the cardiac movements.

The heart is hollow in all mammalia, and in man its cavity is divided by a longitudinal muscular septum into two lateral halves; and each lateral half is again divided by a transverse septum into two cavities, one of which is directed toward the base, the other toward the apex, of the heart.

The four cavities of the human heart are called, respectively, the right auricle and ventricle and the left auricle and ventricle. The auricles are contained in the basilar, the ventricles in the apical, portions of the heart.

The longitudinal septum separating the right and the left cavities is complete; each auricle, however, communicates with the ventricle on the same side by an opening in the auriculo-ventricular septum.

The location of these transverse and longitudinal septa is indicated by furrows on the surface of the heart; these are called the *auriculo-ventricular* and the *interventricular* furrows.

The interior of the heart is lined by a membrane which is called the *endothelium;* it consists of a layer of fibrous tissue, a layer of elastic and muscular fibres, and a single layer of flat, elongated cells supported by a delicate basement membrane.

The blood enters and leaves the heart by vessels which open into its various cavities; several of these openings are supplied with valves, which are merely reduplications of endothelium; they serve to prevent the blood from flowing in the wrong direction.

The cavities of the heart differ in their size, form, and structure.

The *right auricle* has a capacity of about 2 ounces; it is a little larger than the left auricle and its walls are thinner. It consists of a main cavity, called the *sinus venosus*, and a smaller cavity, the triangular accessory portion, called the *appendix auriculæ*. The right auricle has the following openings:

1. The *opening of the superior vena cava*. This vessel returns the venous blood from the upper part of the body and opens into the upper portion of the right auricle.

2. The *opening of the inferior vena cava*. This vessel conveys the venous blood from the lower part of the body and opens into the right auricle just below the superior vena cava.

3. The *coronary sinus*. This is the opening of the coronary vein, which returns the venous blood from the substance of the heart; this opening is situated between that of the inferior vena cava and that in the right auriculo-ventricular septum.

4. The *foramina Thebesii*. These are minute openings of veins from the substance of the heart.

5. The *auriculo-ventricular opening*. This is in the septum separating the right auricle from the left ventricle.

Of these five openings, only that of the coronary sinus is provided with a valve, called the *coronary valve*.

Between the opening of the inferior vena cava and the auriculo-ventricular opening there is a projection of endocardium, called the *Eustachian valve;* it is large and more developed in fœtal life, during which period it serves to direct the current of the blood toward the left auricle. During fœtal life the blood passes directly from the right to the left auricle through an opening in the septum separating these cavities; this opening, the *foramen ovale*, becomes obliterated at birth, but its location remains visible as a depression, called the *fossa ovalis*, located in the sur-

face of the septum; the lower border of the fossa ovalis has a projection called the *annulus ovalis.*

Between the openings of the superior and inferior venæ cavæ there is a prominence called the *tuberculum Loweri;* it is believed that this directs the current of the blood from the venæ cavæ toward the auriculo-ventricular opening.

The interior of the main cavity of the auricle is smooth; the surface of the interior of the appendix auriculæ presents minute muscular projections called the *musculi pectinati.*

The *right ventricle* has a capacity of about 3 ounces; it is triangular in shape, and forms the interior of the apical portion of the right side of the heart; its walls are thinner than those of the left ventricle.

The right ventricle has two openings: 1. The opening of the pulmonary artery. 2. The auriculo-ventricular opening. The *opening of the pulmonary artery* is large and oval. It is situated in the lower portion of the anterior surface of the ventricle near the interventricular septum. This opening is guarded by the *semilunar valve*, consisting of three semicircular folds of endocardium which are attached to the edge of the opening by their convex border, thus forming three pockets; their free border is somewhat thick, and presents at the centre a nodule called the *corpus Arantii*, from which tendinous fibres radiate in the substance of the valve toward its point of attachment. During the flow of the blood from the ventricle into the pulmonary artery the segments of the valve are pressed against the inner side of the vessel. The pulmonary valve serves to prevent a regurgitation of the blood from the pulmonary artery back into the ventricle. The interior of the artery presents a pouch-like expansion behind the flaps of the valve; if the blood regurgitates it fills—this is called the *sinus of Valsalva*—and the flaps are expanded; the triangular opening left in the middle, where the free borders of the three flaps meet, is completely closed by the *corpora Arantii*, and thus a regurgitation is prevented.

The *auriculo-ventricular opening* on the right side is guarded by a fold of endocardium which is called the *tricuspid valve;* it consists of three segments, trapezoidal in form, which are attached to the margin of the auriculo-ventricular opening and also to each other; from their free border and from their ventricular surface delicate tendinous cords, called the *chordæ tendineæ*, pass into the ventricular cavity and are attached to the *columnæ carneæ*, little muscular projections from the surface of the interior of the ventricle; some of these columnæ carneæ are not attached to the tendinous cords, but are attached their entire length, or simply at one end, to the surface of the cavity, thus forming small ridges and loops.

The *left auricle* has a capacity of about 2½ ounces; its walls are thicker than those of the right auricle, and consequently its cavity is smaller.

The left auricle also consists of a *main cavity* and an *appendix auriculæ*. The surface of the former is smooth; from that of the appendix a small number of *musculi pectinati* are projected. The two auricles are separated by a complete septum, called the *septum auriculorum*.

The openings into the left auricle are:

1. The openings of the *four pulmonary veins*, located in the posterior walls of the auricle.

2. The *auriculo-ventricular opening*, by which the auricle communicates with the ventricle.

There are no valves in the left auricle. The *left ventricle* has a capacity of about 3 ounces; it is longer and has thicker walls than the left ventricle, projects beyond it, and forms the apex of the heart.

It has two openings, namely:

1. The aortic opening.

2. The auriculo-ventricular opening. The *aortic opening* is circular and is located in front and to the right of the auriculo-ventricular opening. This opening is guarded by the *semilunar valve*, which has the same structure as

the semilunar valve guarding the pulmonary artery. The pouch-like expansion behind the flaps of the aortic semilunar valve is deeper; it is also termed the *sinus of Valsalva*, or *sinus aorticus.*

The *auriculo-ventricular* opening is located in the auriculo-ventricular septum; it is guarded by a valve called the *mitral* or *bicuspid valve.* It consists of two segments attached to the edges of the opening and to each other.

The anterior segment, which is placed between the auriculo-ventricular and the aortic openings, is larger and stronger than the posterior. To the free border of the segments and to their ventricular surface are attached the tendinous cords, or *chordæ tendineæ*, which, in the same manner as in the right ventricle, are attached to the free ends of the *columnæ carneæ.* The two *musculi papillares* are more prominent and give attachment to most of the chordæ tendineæ. The columnæ carneæ are most abundant in the apical portion of the ventricle; they are arranged similarly to those in the right ventricle. The interventricular septum is thick toward the apex, but thin and fibrous in the upper part.

The *walls* of the cavities of the heart are composed of involuntary muscular fibres; they are so arranged that their contraction causes a diminution of the cavities.

The muscular fibres of the auricles are separated from those of the ventricles by a fibrous ring called the *annulus atrio-ventricularis.*

The muscular fibres of the auricles are arranged in two layers: an *outer layer*, consisting of transverse fibres which surround both auricles, and an *inner layer*, consisting of (*a*) longitudinal and oblique fibres which are inserted anteriorly and posteriorly into the annulus atrio-ventricularis; (*b*) transverse fibres which pass around each auricle and which, between the two, form the interauricular septum; (*c*) circular fibres which surround the openings of the

vessels into the auricles and by their contraction close these openings.

The muscular fibres of the ventricles are arranged in a more complicated manner. The left ventricle is larger than any of the cavities, and its walls are thicker. The left side of the anterior surface, the main part of the posterior surface, and the apex of the heart form the outer walls of the left ventricle.

The muscular walls of the left ventricle are generally formed by seven layers of spiral fibres; these are inserted in the annulus atrio-ventricularis, and wind around the ventricle, passing deeper and deeper into the substance of the wall. The fibres anteriorly attached to the annulus atrio-ventricularis pass downward obliquely and around the apex from right to left; those attached posteriorly to the annulus atrio-ventricularis pass downward obliquely from left to right and wind around the apex. The external layers of the spiral muscular fibres pass around the lower portion of both ventricles ; they pass into the substance of the apex and finally terminate at the columnæ carneæ or musculi papillares of the left ventricle.

The deeper layers of these spiral muscular fibres become shorter and shorter, and surround only the upper portion of the left ventricles. The walls of the lower or apical portion of this are thinner, as the apex is formed only by the longer and more superficial muscular fibres. The fibres forming the walls of the right ventricle are similarly arranged; they are shorter, more delicate, and do not enter into the apex of the heart.

The muscular part of the interventricular septum is formed by the meeting of the fibres from the right and left ventricles. The blood-supply reaches the substance of the heart through the right and left coronary arteries, two vessels which arise from the aorta immediately above the semilunar valves.

The venous blood from the substance of the heart is

conveyed into the right auricle by the coronary veins and by the venæ cordis minores.

The nerve-supply to the heart is from branches of the sympathetic and pneumogastric nerves; several nerve-centres are located in the substance of the heart.

For the physical examination of the heart, for the study of heart-sounds, and for the diagnosis of cardiac diseases, especially those of the valves, called lesions, it is necessary to be familiar with the location of the various anatomical structures of the heart. As you will receive a practical course in the examination of the heart, I will speak but briefly on this subject.

1. The *auricles* are on a line with the third costal cartilages. The *right* auricle extends a little beyond the right border of the sternum. The *left* auricle is covered by the pulmonary artery and lies behind the cartilage of the third left rib.

2. The *ventricles* occupy a space behind and to the left of the sternum, extending from the third to the fifth intercostal space. The *right* ventricle lies principally behind the sternum, while a small portion of it extends to the left of that bone. The *left* ventricle lies still more to the left of the sternum, extending to an imaginary line drawn vertically half an inch from the left nipple.

The whole anterior surface of the heart is covered with lung tissue, with the exception of a small triangular portion of the right ventricle.

The relative positions of the valves are as follows:

1. The *tricuspid* valve lies behind the middle of the sternum, on a line with the sternal articulation of the fourth rib.

2. The *pulmonary semilunar* valves lie behind the articulation of the third left rib with the sternum. The pulmonary artery rises from the right ventricle behind the sternum near its left border, and on a level with the sternal articulation of the third rib; it ascends and then passes backward.

3. The *mitral* valve lies behind the costal cartilage of the fourth left rib near the border of the sternum.

4. The *aortic semilunar* valves lie behind the sternum near its left border, and just below the sterno-costal articulation of the third rib. The aorta rises from the left ventricle behind the sternum near its left border, and on a level with the third intercostal space; the aorta then passes upward and to the left.

The Arteries.

The blood-vessels which convey the blood from the heart to the tissues are called the *arteries.* The normal structure of these vessels is an important factor in the circulation of the blood.

The walls of the arteries are composed of three coats—namely; the *outer* coat, or *tunica adventitia;* a *middle* coat, or *tunica media;* and an *inner* coat, or *tunica intima.*

The *outer* coat, or *tunica adventitia*, is composed principally of fibrous tissue and contains elastic fibres.

The *middle* coat, or *tunica media*, consists of non-striated muscular and elastic fibres in alternating layers. In the larger arteries the elastic element is predominant; in the smaller arteries muscular fibres are more abundant; while in the smallest arteries, or arterioles, the middle coat contains only muscular fibres.

The presence of elastic fibres in the external and middle coats of the arteries prevents them from collapsing when empty. On a cut surface the lumen can be plainly seen.

The *tunica intima* consists of a delicate fibrous membrane which contains elastic fibres, and, in the larger arteries, muscular fibres as well. It has a fenestrated structure; it is therefore called the *fenestrated membrane.* In the smaller arteries this membrane does not present this characteristic structure. Within this is the endothelium which lines all blood-vessels; it consists of elongated, flat cells disposed in a single layer upon a delicate basement membrane.

The Capillaries.

The capillaries are minute, delicate blood-vessels which freely anastomose in the tissues, through the walls of which the materials intended for the nutrition of the tissue elements transude into the interstices of the tissues.

The *walls* of the capillaries consist of a single layer of flat endothelial cells which are cemented together at their sides; between these cells minute openings, called *stomata*, appear at intervals.

The Veins.

The blood-vessels which convey the blood from the tissues to the heart are called *veins*. They differ in their structure from the arteries in that their lumen is larger and their walls are thinner and contain but few elastic fibres. The walls of the veins, like those of the arteries, consist of three coats.

The *tunica adventitia* is thicker than in arteries; it is composed mainly of fibrous tissue containing some elastic and muscular fibres.

The *tunica media* is thinner than in arteries; it is composed of muscular fibres with few elastic fibres.

The *tunica intima* has the same structure as that of the arteries; the larger veins also have a fenestrated membrane, and in some of these the membrane between the fenestrated membrane and the endothelium contains some elastic fibres.

The larger veins in certain locations in the body—for instance, those in the neck and extremities—are supplied with *valves;* these are flaps projecting into the lumen of the veins. They are composed of fibrous tissue containing elastic and muscular fibres, and a covering of endothelium on both sides. These valves serve to prevent a regurgitation of the blood.

The venous blood from the brain is returned through

channels formed by folds of the dura mater lined with endothelium; such a channel is termed a *sinus*.

The walls of the blood-vessels are supplied with blood for their nutrition by minute vessels which are called the *vasa vasorum;* their structure is the same as that of other blood-vessels.

The nerves supplying the walls of the blood-vessels rise from nerve-centres and pass along with other fibres in large nerve-trunks terminating in the muscular fibres of the coats of the blood-vessels.

LECTURE XXII.

THE HEART'S ACTION.

THE physiological activity of the heart consists of a rhythmical contraction and relaxation of its auricles and ventricles.

A *cardiac pulsation*, or *revolutio cordis*, consists of three stages, namely:

1. A contraction of both auricles.
2. A contraction of both ventricles.
3. A period of rest, during which the auricles and ventricles relax.

The events which take place during such a cardiac *cyclus* may be enumerated as follows:

1. The auricles fill with blood and dilate, the right auricle receiving the blood from the superior and inferior venæ cavæ and from the coronary veins, the left auricle receiving blood from the pulmonary veins.

2. When the auricles are completely filled they begin to contract; the contraction begins at the appendices of the auricles, by which the blood is forced into the main cavity of the auricles; the contraction of their walls then continues from above toward the ventricles. During this stage the openings of the veins into the auricles are closed by the contraction of the circular fibres surrounding these openings, and a regurgitation of blood into these vessels is thus prevented. The pressure exerted upon the blood in the auricles by the contraction of their walls forces the blood through the opening in the auriculo-ventricular septa into the ventricles.

3. The ventricles are filled by the blood forced into them

from the auricles; the ventricles dilate, and when filled begin to contract; the segments of the mitral and tricuspid valves, owing to their thinness, float on the blood, and are so raised against the auriculo-ventricular openings, thus preventing a regurgitation of blood into the auricles during the contraction of the ventricles. The contraction of the ventricular walls upon the blood forces it into the openings of the aorta and pulmonary artery.

4. The ventricles begin to relax; the blood forced into the aorta and pulmonary artery tends to regurgitate, but is prevented from re-entering the ventricles by the semilunar valves, which become closed by the filling of the sinuses of Valsalva behind the pouches of the flaps of the semilunar valves.

The simultaneous contraction of the auricles is termed the *auricular systole*, or *systole atriorum;* that of the ventricles is termed the *ventricular systole;* and the period during which both auricles and ventricles are in a state of relaxation is termed the *diastole*.

The average duration of such a cardiac cyclus in the healthy human adult is 0.72 second. If this time is divided into six equal parts, then the various phases of a cardiac cyclus are as follows:

During periods 1 and 2 the auricles are in a state of contraction, the ventricles in a state of relaxation.

During periods 3, 4, and 5 the auricles are in a state of relaxation, the ventricles in a state of contraction.

During period 6 both auricles and ventricles are in a state of relaxation.

From this the time taken up by each phase of the cardiac cyclus can be easily calculated.

The auricular contraction taking place during periods 1 and 2 takes up two-sixths of the whole time of a cardiac cyclus.

The auricular relaxation taking place during periods 3, 4, 5, and 6 takes up four-sixths of the whole time.

The ventricular contraction taking place during periods 3, 4, and 5 takes up three-sixths, and the ventricular relaxation taking place during periods 6, 1, and 2 also takes up three-sixths of the whole time of a cardiac cyclus. The phase of diastole—that is, when both auricles and ventricles are in a state of relaxation—takes place during period 6; therefore it takes up one-sixth of the whole time of the cardiac cyclus.

The number of cardiac pulsations per minute is from 65 to 75 in the average healthy human adult, 180 in the fœtus, 150 in new-born children, 100 in the first years of infantile life; it then gradually diminishes until its normal frequency is reached; in old age it is slightly increased. The action of the heart is most regular in rhythm and frequency when the body is at rest and in a horizontal position. The frequency of the cardiac pulsations is increased by motion, excitement, walking, and the taking of nourishment; it is decreased by fasting. Many pathological conditions increase or decrease the action of the heart and influence the rhythm. The physiological action of the heart is muscular and is ordinarily dependent upon proper nerve influence, and it is therefore necessary to study and understand the nervous system of the heart.

The heart receives nerve-fibres from the pneumogastric and sympathetic nerves through the *cardiac plexus;* besides these there are located in the substance of the heart itself the so-called inherent ganglia.

The *inherent ganglia* are small ganglionic masses of nerve substances; they are located principally in the inter-auricular and auriculo-ventricular septa. These ganglia communicate with each other by delicate fibrillar processes, and numerous fibres from these ganglia are distributed throughout the substance of the heart, terminating in its muscular fibres. *Remak* first described these ganglia.

The experiments of *Stannius* demonstrated that these ganglia are motor ganglia and that they act automatically.

When the nerve-fibres which are distributed to the heart from the cardiac plexus are cut the heart will continue to beat; this shows that the cause of the heart's action is located in the substance of the organ, and it also shows that the activity of the centres or ganglia in the heart is not dependent upon external nerve influence.

The largest and most important automatic motor ganglion of the heart is located in the interauricular septum, and from this the stimulus is transmitted to the others; this explains why the rhythmical contractions of the cardiac muscle begin in the auricles.

The *cardiac plexus* is formed by branches from the pneumogastric and sympathetic nerves. The plexus is located near the base of the heart and is divided into a deep and a superficial portion. The *deep* cardiac plexus is situated between the trachea and the aorta; its branches form the posterior coronary plexus, from which fibres are distributed to the posterior wall of the heart. The *superficial* cardiac plexus is situated in the concavity of the arch of the aorta; its branches form the anterior coronary plexus, from which fibres are distributed to the anterior wall of the heart.

The cardiac plexus contains vasomotor, sensory, inhibitory, and acceleratory fibres, which are distributed to the heart.

The *inhibitory* fibres rise from a centre which is located in the medulla oblongata in the apex of the calamus scriptorius; an irritation of this centre causes a decrease in the cardiac contractions. The inhibitory fibres pass in the pneumogastric nerve to the cardiac plexus. Section of the pneumogastric nerves causes an accelerated heart-action.

The *acceleratory* fibres rise from centres which are located in the brain and upper portion of the spinal cord. Irritation of the medulla oblongata or upper cervical portion of the spinal cord causes an accelerated heart-action. From their centres these accelerating nerve-fibres pass

down in the spinal cord, leave the canal with the cervical and upper dorsal nerves, and these communicate with the last cervical and first dorsal ganglia of the sympathetic nerve, from which branches are distributed to the cardiac plexus

The heart is evidently supplied with sensory nerve-fibres; this is shown by the pains experienced in certain heart-diseases. These fibres are probably derived from the pneumogastric.

From this description of the nervous mechanism of the heart we learn, therefore, that the motions of the organ are caused by the action of the *inherent automatic motor ganglia*, and that the rhythm of these motions is regulated by the influence of nerves which are connected with centres in the brain and medulla. The stimulus for the normal activity of these centres is the same as that for all nerve-centres—namely, a proper exchange of the gases in the blood.

The rhythmical motions of the heart produce certain changes in its position and in its form.

The heart is attached by its base to the large vessels, consequently only its body and apex are movable; changes in its position must therefore be coincident with the motions of its apical or ventricular portion. During the ventricular systole the main part of the heart rotates on its axis forward and to the right, the apex twists forward to the right and upward ; this peculiar motion is due to the peculiar anatomical arrangement of the ventricular fibres. During the relaxation of the ventricles the reverse changes in the position of the heart take place.

The changes in the form of the heart during its motions may be described as follows: During its contraction there is a shortening of the longitudinal and a narrowing of the transverse diameter anteriorly, while posteriorly the longitudinal diameter is lengthened; these changes are caused by the muscular fibres of the ventricles and the tilting forward of the apex of the heart. This forward motion of

the heart's apex can be easily felt with the hand; it is also perceptible to the eye by the elevation of the chest-wall in the fifth intercostal space on the left side of the sternum. This phenomenon produced by the cardiac motions is called the *apex beat*, the *cardiac impulse*, or *ictus cordis;* it is synchronous with the ventricular systole. During activity there are produced certain sounds which are called the *heart-sounds;* they are two in number and can be heard by placing the ear over the cardiac region; they are known as the *first* and *second* heart-sounds. The *first* sound is muscular, produced by the contraction of the fibres of the ventricles; it is strengthened by the vibrations of the chordæ tendineæ and by the sound produced by the closing of the mitral and tricuspid valves. The first heart-sound is dull, deep, and long; it is most distinctly heard over the apex in the fifth left intercostal space.

The *second* heart-sound is produced by the closing of the semilunar valves of the aorta and pulmonary artery, and is heard directly over these valves. It is short, clear, and high-pitched, and immediately follows the first heart-sound. Between the first and second sounds there is a period of silence.

The normal action of the heart and the phenomena accompanying it are often altered in many pathological conditions. The rhythm of the pulsations, their strength, and the periods of the various phases of a cardiac pulsation may be altered. The cardiac impulse, or apex-beat, may be abnormally strong or weak, or it may be perceptible in an abnormal location. The sounds of the heart may be changed in their character. In certain valvular diseases abnormal sounds are produced within the heart; they are described as *cardiac murmurs.*

The circulation of the blood is maintained principally by the action of the heart, by which the necessary variations of the blood-pressure in the different parts of the circulatory system are maintained.

The *blood-pressure* is the pressure which the column of blood exerts perpendicularly upon the walls of the vessel which it fills. If the blood-pressure were equal in all parts of the circulatory system the blood would not circulate; but, as the pressure is greater in one part than in another, the blood will flow in the direction where it finds the least resistance. In the animal body these necessary variations of the blood-pressure are maintained by the action of the heart. During each diastole the auricles draw into themselves a quantity of blood from the venous circulation, and at each systole the ventricles force a quantity of blood into the arterial circulation. At each cardiac pulsation, therefore, the blood-pressure is decreased in the venous system and increased in the arterial, and the result is that the blood circulates from the arterial to the venous side. The blood-pressure in the vascular system is furthermore regulated by the properties of the walls of the blood-vessels and by other auxiliary factors, such as muscular pressure, respiratory movements, etc.

To measure the blood-pressure a glass canula is introduced into the blood-vessel; the canula is connected by means of a rubber tube with a mercurial manometer; the connecting tube is filled with a saline solution; the pressure of the blood in the vessel is transmitted by the saline solution to the column of mercury in the manometer and causes a rise of the mercury in the graduated tube. The height of the column of mercury multiplied by its transverse diameter is the weight of the mercury raised by the blood-pressure.

Experiments have shown that the blood-pressure in the aorta is about 4 pounds and 4 ounces, whereas the blood-pressure in the radial artery is only about 4 drachms.

The blood-pressure is greatest in the left ventricle of the heart; it is greater in the aorta and in the larger arteries than in the smaller. It diminishes in the arteries as the sectional area of their calibre increases.

The blood-pressure in the arteries is *increased:*

1. By a forcible and increased heart-action.

2. By an increase of blood in the arteries.

3. By a decrease in the calibre of the lumen of the arteries; as, for instance, by muscular pressure, or by a contraction of the muscular fibres of the arteries.

4. By expiration, since this increases the intrathoracic pressure.

5. By an increase in the resistance which the current of the blood has to overcome.

The blood-pressure in the arteries is *decreased:*

1. By a weak heart-action.

2. By a decrease in the quantity of the blood in the arterial system.

3. By the increase in the lumen of the arteries.

4. By the diminution of the resistance presenting itself to the current of blood.

5. By inspiration, since this decreases the intrathoracic pressure.

The blood-pressure in the capillaries cannot be directly measured, owing to the minute calibre of these vessels; it has been estimated that the pressure of blood in them is about 20 to 60 milligrammes. This pressure is increased: 1. By an increase of the blood-pressure in the arterial system. 2. By obstructions in the venous system. The reverse conditions decrease the blood-pressure in the capillary system.

The blood-pressure in the veins is much less than that in the arteries; it is very inconstant. It is greater in the smaller veins, and decreases as the lumen of the vessels increases.

The blood-pressure in the veins is principally influenced by:

1. The arterial and capillary blood-pressure.

2. The quantity of blood in the veins.

3. The position of the body.

The variations in the blood-pressure in the system are recorded by means of an instrument which is called the *kymograph*. It consists of a U-shaped glass tube partially filled with mercury; one end of this tube is connected by a rubber tube with a glass canula which is inserted in the blood-vessel parallel with its long axis; the connecting tube is filled with a saline solution, which transmits the pressure of the blood to the column of mercury in the U-shaped tube, and any changes in the blood-pressure are indicated by a rising or sinking of the column of mercury in the free end.

These variations are recorded permanently upon a revolving strip of paper by a piston which floats upon the column of mercury and which is connected with a pencil. A tracing indicating the blood-pressure in a vessel shows various elevations and depressions. The more perpendicular elevations and sudden descending lines indicate the increase and decrease during the systole and diastole of the heart; the more wavy lines in the tracing indicate the variations of the blood-pressure caused by the respiratory movements.

Inspiration causes an increase in the thoracic cavity by an expansion of its walls and a descent of the diaphragm; the pressure upon the heart and interthoracic viscera is diminished; the heart expands and aspirates a quantity of blood from the venous circulation, thus decreasing the blood pressure in the vessels. Expiration causes a decrease in the thoracic cavity; its walls are retracted, the diaphragm raised, and thus the intrathoracic pressure upon the heart and blood-vessels is increased; moreover the contraction of the heart forces a quantity of blood into the arterial system, thus increasing the blood-pressure in the vessels.

The blood in the human body circulates from the left side of the heart into the arterial system; by circulating in the capillaries the blood is freely distributed to all parts of the tissues, and is returned from them as venous blood into

the right side of the heart. The right auricle receives venous blood from the superior and inferior venæ cavæ and from the veins of the heart substance; from the right auricle the blood passes through the right auriculo-ventricular opening into the right ventricle; from this the venous blood is conveyed by the pulmonary artery through the lungs, where it becomes oxygenized, and is returned as arterial blood by the pulmonary veins into the left auricle; from this the blood passes through the left auriculo-ventricular opening into the left ventricle, and thence into the aorta and arterial system.

The factors of the circulation of the blood through the *heart* are as follows: The flow of the blood from the superior and inferior venæ cavæ and from the cardiac veins into the right auricle, and the flow of the blood from the pulmonary veins into the left auricle, is caused: 1. By the force of the blood in these vessels—that is, the force from behind.

2. The suction in front is caused by the vacuum produced in the auricles by their dilatation. From the auricles into the ventricles, and from these into the arterial system, the blood is forced by the contraction of the muscular walls of the heart.

The factors of the circulation of the blood in the *arteries* are:

1. The ventricular contractions of the heart.
2. The elasticity of the coats of the arteries.

At each ventricular contraction the heart forces about 150 to 180 grammes of blood into the arteries, thus suddenly increasing the blood-pressure in these vessels; owing to the elasticity of the walls of the arteries their distension is partially neutralized, and the reaction of the elastic walls upon the columns of blood causes a flow in the direction where it finds the least resistance—namely, toward the veins; a regurgitation of the blood into the heart is prevented by the closing of the semilunar valves. The flow

of the blood in the arteries becomes gradually more continous as their calibre decreases.

The flow of the blood in the capillaries is from the arterial to the venous side, owing to the greater pressure in the former. The flow of the blood in the capillaries is continuous and regular. In the capillaries the current of blood meets the greatest resistance, owing to the minute calibre and many ramifications of these vessels, and owing to the great friction the blood is subjected to by its contact with the large amount of surface presented in the walls of the capillaries.

The factors which cause and influence the flow of the blood in the *veins* may be enumerated as follows:

1. The pressure of the blood from behind.
2. The relaxation of the vessels in front, produced by the aspiration of blood into the auricles of the heart.
3. The activity of the muscular fibres of the walls of the veins.
4. The valves in the interior of the veins.
5. The gravity of the blood.
6. The pressure of muscles.
7. The respiratory movements.

The rapidity with which the blood circulates in the various parts of the system has been observed and studied by experiments, with the following results: It is greatest in the arteries, and diminishes as the blood flows from the heart to the veins and again to the heart. The rapidity of the flow is greater in the large than in the smaller arteries, and it diminishes proportionally as the sectional area of the arteries at a given point increases. From experiments it has been estimated that the blood in the aorta flows at the rate of 400 millimetres a second, whereas in the capillaries it flows at a rate of only 0.8 millimetre per second. In the veins the rapidity of the flow of the blood is inconstant; it diminishes in proportion as the calibre of the veins increases.

The time which is required for the blood to pass once through the whole circulatory system has been estimated to be 23.2 seconds at the rate of 72 cardiac pulsations per minute.

The physiological condition of the walls of the blood-vessels must also be considered an important factor in the circulation of the blood. Normally the walls of the blood-vessels are maintained in a constant state of partial contraction, a condition which is called the *tonus* of the blood-vessels. It depends upon nerve influence; it is therefore necessary to study the nervous system of the blood-vessels. The walls of all blood-vessels are supplied with nerve-fibres which arise in nerve-centres and terminate in the muscular fibres of the walls. These nerve-fibres are divided into *vasomotor* or *vasoconstrictor* and *vasodilator* fibres; the names indicate their functions. The centres from which these fibres arise are called *vasomotor* and *vasodilator nerve-centres.* In the walls of the blood-vessels there are located the so-called vascular nerve-centres.

The *vasomotor* or *vasoconstrictor* nerve-fibres arise from nerve-centres, one of which is located in each side of the medulla oblongata; from these the fibres pass down in the lateral columns of the cord and leave the spinal canal together with the anterior roots of the spinal nerves, and these unite with spinal, cranial, and sympathetic nerve-trunks and are distributed from these to the walls of the blood-vessels. The trunks of the cervical, sympathetic, of the splanchnic, and of many spinal nerves—as, for instance, the ischiatic nerve—contain vasomotor fibres in abundance. Section of such nerve-trunks causes a dilatation, stimulation of the same, a contraction of the vessels in the regions supplied by these nerves.

The *vasomotor centres* from which these fibres arise are *automatic;* their normal activity is not due to peripheral stimuli. Under certain circumstances these centres are abnormally irritated by stimuli received through periphe-

ral sensory nerves. Certain psychical events, such as shock, fright, fear, etc., cause a sudden paleness, resulting from a contraction of the blood-vessels; this is then a reflex act resulting from an abnormal irritation of the vasomotor centres by a stimulus received through sensory nerves.

The *vasodilator* fibres arise from centres the exact location of which has not yet been demonstrated. The fibres are, like the vasomotor fibres, contained in sympathetic, cranial, and spinal nerve-trunks, and terminate in the muscular fibres of the walls of the blood-vessels.

The influence of these nerve-fibres can be compared to that of the inhibitory fibres of the pneumogastric nerve on the heart. It has been observed that certain events produce a sudden dilatation of the blood-vessels; this must be considered as an abnormal irritation of the vasodilator centres by a stimulus received through peripheral sensory nerves; blushing must be considered a reflex act so produced.

The *vascular centres* located in the walls of the blood-vessels evidently influence their tonus. It is a well-known fact that cold produces a contraction, warmth a dilatation, of the blood-vessels; this may probably be a reflex act caused by the thermal influence on the peripheral sensory nerves, but observations tend to show that the effect produced is mainly due to an abnormal stimulation of the vascular centres in the walls of the blood-vessels.

LECTURE XXIII.

THE PULSE AND THE TECHNIQUE OF ITS EXAMINATION.

Before finishing the subject of the blood circulation I will speak of the method which is generally employed in studying the strength and rhythm of the cardiac pulsations and the condition of the blood-vessels; this is the examination of the pulse.

The sudden distension of the arterial walls which is caused by each ventricular systole, and the reaction of the elastic arterial coat upon the column of the blood, is perceptible both to the eye and to the touch as a sudden elevation or distension and a more gradual relaxation of the arterial walls; this is called the *pulse*, and is more pronounced in the larger than in the smaller arteries. The pulse indicates the strength and rhythm of the cardiac pulsations and the condition of the arterial walls. These principal factors of the circulation are often influenced by pathological conditions; the pulse, therefore, is a very important aid in physical examination. Even ancient writers like *Hippocrates*, *Herophilus*, and *Galenus* mentioned in their writings the importance of pulse examination in disease. In order to study the pulse in disease it is necessary to be fully familiar with the character of the healthy pulse, and, furthermore, with the technique of pulse examination.

In examining the pulse the examiner's index and middle fingers are placed with a gentle, even pressure upon the radial artery at the lower end of the radius. The examiner must observe the frequency, the strength, and the rhythm of the pulsations and the character of the arterial walls.

1. The *frequency* of the pulse. In the healthy adult man the pulse beats about 72 times, in women about 80 times per minute. The pulse of a new-born infant beats from 120 to 150 times per minute; it then decreases in frequency until about the twentieth year; from that time until the fiftieth or sixtieth year it remains the same; in old age its frequency again increases. The frequency of the pulse in health is influenced by various conditions; it is most regular when the body is at rest and in a horizontal position. The pulse is more frequent when the body is erect; its frequency is increased by muscular activity, excitement, mental or sexual irritation, and often by the taking of food; it is decreased by fasting. Variations in the atmospheric pressure influence the frequency of the pulse; this is increased when the atmospheric pressure is decreased, and *vice versa*. The frequency is much altered by pathological conditions. It is increased in all febrile conditions, and in many chronic and wasting diseases. Its frequency is decreased in many cerebral diseases. Cardiac lesions also influence the frequency of the pulse. An abnormally quick pulse is termed *pulsus frequens*, and an abnormally slow pulse a *pulsus rarus*. In many pathological conditions the frequency of the pulse is increased to 130 and 150 beats per minute, and in a condition termed *pyknocardia* a pulse-frequency of 250 beats per minute has been observed. Abnormal decrease of the pulse-frequency is often an alarming symptom of disease; in a condition termed *spaniocardia* the pulse sometimes only beats 40 times per minute. Many drugs influence the pulse-frequency—for instance, digitalis decreases, while other drugs, like atropine, belladonna, strychnine, increase the frequency It is therefore necessary, when examining the pulse as to its frequency, to consider the many conditions which influence it.

2. The *rhythm* of the pulse. In the normal pulse the beats follow at regular intervals. This rhythm is altered

in many pathological conditions, and often indicates cardiac lesions. The rhythm of the pulsations may be so altered that their regularity is interrupted by the skipping of a beat—the pulse is then called a *pulsus intermittens;* or the regularity is interrupted by an intercurrent beat, and the pulse is then called *intercurrent.*

3. The *strength* of the pulse is often altered, and is indicative of changes in the strength of the cardiac pulsations, and also of abnormal conditions of the walls of the blood-vessels. The pulse may be abnormally strong or hard, or weak and soft; the hardness and softness of the pulse indicate changes in the structure of the walls. The pulse may be large and full, or it may be small; these alterations are indicative of the quantity of blood in the vessels.

4. The *character* of the walls of the blood-vessels can be ascertained by studying the pulse; this is sometimes small and hard, or soft and wiry, or quick and jerky; these differences are principally due to changes in the tonus of the vessels, or to pathological changes in their walls, such as impaired elasticity or abnormal increase of fibrous tissue.

In patients with high fevers the frequency of the pulse is generally proportionally increased, and often has a peculiarity which is known as *dicrotism.* In this condition each pulsation consists of two beats; the first is large and is suddenly followed by a smaller beat. This peculiarity is produced by the frequent but weak ventricular systole and the consequently more forcible secondary distension of the arterial walls, produced by a rebounding of the blood from the closed semilunar aortic valves.

Many instruments have been devised for a more definite and exact study of the pulse and for the recording of its conditions. The instrument employed for this purpose is the *sphygmograph*, of which several kinds, differing in their structure, exist.

I will describe the sphygmograph devised by *Marey*, of Paris, in 1860, which instrument has been greatly improved

since that time. It consists of a metallic frame with an arrangement for its adjustment to the arm of the patient by means of straps ; to the frame is attached a spring, and to the free end of this a rounded button, which by the force of the spring is slightly pressed upon the blood-vessel, generally the radial artery ; this button consequently follows the up-and-down motions of the walls of the blood-vessels. With the button is connected a rod which transmits its movements to a lever ; at the free end of this is fastened a pen or pencil which records the movements of the button, transmitted by the lever upon a long strip of paper ; this is fastened to a vertical plate which is moved by clockwork, on a rail, at a uniform rate. The slip of paper passes the point where the recording pen or pencil moves up and down in ten seconds, and in that time the pencil marks on the paper a tracing which is known as the *sphygmogram.* A sphygmographic tracing consists of a wavy line, the ascending portions of which indicate the sudden distension of the arterial walls by the ventricular systole ; the descending portions are more wavy, showing generally several secondary elevations, which indicate the gradual relaxation of the arterial walls during the cardiac systole. The angle or apex formed at the point where the ascent terminates and the descent begins indicates the point of the maximal distension of the arterial walls. The descending portions in the sphygmographic tracing have, as I have stated above, several secondary elevations. The first one of these is in the upper third and is the most prominent one ; it is produced by the blood rebounding from the closed semilunar aortic valves, which causes a secondary distension of the arterial walls. The other minor elevations in the descending portions are produced by the vibrations of the elastic arterial walls. A careful inspection of the sphygmogram will show that the whole tracing has a wavy appearance, produced by the increase and decrease of the blood-pressure during the respiratory

movements. The sphygmogram therefore indicates the following:

1. The number of cardiac pulsations in the time of ten seconds. In the healthy adult the pulse beats from 72 to 80 times a minute, or about 12 times in ten seconds. On the sphygmogram each pulsation is represented by an ascending line, a summit, and a descending line. A smaller number than 12 of such figures in the sphygmogram would therefore indicate a decrease, a larger number an increase, in the cardiac pulsations.

2. The force of the ventricular systole is indicated by the sudden ascent and height of the ascending portion; normally this line ascends very slightly obliquely, almost vertically.

3. The condition of the elastic walls, indicated by the oblique descent and secondary elevations of the descending line. A slow or sudden descent or absence of secondary elevations indicates a lack of elasticity of the arterial walls.

4. The rhythm of the cardiac pulsations is indicated by the regularity of the ascending and descending lines in the sphygmogram.

The sphygmograph is principally employed as an aid in the diagnosis of diseased conditions of the blood-vessels and valvular lesions of the heart.

The most frequent pathological condition of the arterial walls is a loss of their elasticity. In the sphygmographic tracing this is indicated by the sudden secondary elevation which is seen high in the descending line, and the slight minor secondary elevations.

The more frequent valvular lesions, in the diagnosis of which the sphygmograph is considered a valuable aid, are: aortic regurgitation, aortic obstruction, mitral regurgitation, and mitral obstruction.

Aortic regurgitation consists of an insufficiency of the aortic semilunar valves, and consequently some of the

blood will be forced back into the left ventricle by the force of the elastic walls exerted upon the blood which is forced into the aorta at each ventricular systole; the result is that the walls of the arteries will relax much more quickly. This is indicated in the sphygmographic tracing by the suddenness of the line of descent.

Aortic obstruction is a lesion in which during the ventricular systole the blood is forced but gradually into the arteries. This is indicated by an obliquity of the ascending line, which is interrupted and assumes a more oblique course as the summit is reached. This peculiarity in the tracing is produced by the gradual distension of the arterial walls.

Mitral regurgitation is caused by an insufficiency of the mitral valve, so that during the ventricular systole a quantity of blood is forced back into the auricle, thus diminishing the quantity of blood forced into the arterial system, and causing a consequently slower reaction of the arterial walls upon the column of blood in them. This is indicated, first, by the shortness of the ascending line; second, by the great obliquity of the descending line in its upper portion.

Mitral obstruction is a lesion in which during the auricular contraction only a small quantity of blood is forced into the left ventricle; consequently, during the systole of this, only a small quantity of blood is forced into the arterial system; the blood-pressure is therefore small, as recognized by the easily compressed pulse. It is for this reason that the sphygmogram shows no peculiarity except a smallness and irregularity of the ascent and descent of the line.

The exact clinical value of the sphygmograph is not fully determined, but it is evident that it is of great use in determining the extent of certain valvular lesions and the degree of pathological changes in the arterial walls by repeated sphygmographic observations upon a patient. The

clinician is, to a certain extent, enabled to also determine the progress of valvular lesions and of cardiac and arterial structural changes.

The Blood Circulation in the Fœtus.

The fœtus receives its blood from the mother through the placental vessels, and the venous blood is not oxygenized in the lungs of the fœtus, because it does not breathe; it is therefore returned by the placental vessels to the mother. The fœtal heart presents certain peculiarities. The septum between the two auricles has an opening, the *foramen ovale*, by which the right auricle communicates directly with the left; this opening has a prominent border, the *annulus ovalis*, which projects into the right auricle. Between the opening of the inferior vena cava and the auriculo-ventricular opening there is another projection from the surface of the auricular cavity; this is known as the *Eustachian valve*, and is believed to direct the current of the blood from the venæ cavæ toward the foramen ovale. The latter opening closes immediately after birth; the remains of it and those of the obliterated Eustachian valve and annulus ovalis remain visible even in the heart of the adult. The fœtus receives *arterial blood* from the mother—*i.e.*, from the placenta—by the *umbilical* vein, which is contained in the umbilical cord. The umbilical vein enters the abdomen of the fœtus at the umbilicus; in the abdomen it passes along the suspensory ligament of the liver to the under-surface of that organ, where it gives off branches to the *left lobe* and to the *lobus quadratus* and *lobus Spigelii* of the liver. The umbilical vein then continues to the transverse fissure, and here it divides into two branches; one of these joins the portal vein and enters the right lobe; the other, called the *ductus venosus*, passes upward and joins the left hepatic vein at its junction with the inferior vena cava; this vessel therefore receives the blood from the portal vein, the hepatic veins, the blood

from those branches of the umbilical vein which are distributed to the liver, the blood from the ductus venosus, and, lastly, the venous blood from the lower part of the body of the fœtus. The inferior vena cava conveys the blood to the right auricle of the fœtal heart, and from this it passes, guided by the Eustachian valve, through the foramen ovale into the left auricle; this also receives a small quantity of blood from the fœtal lungs by the pulmonary veins. From the left auricle the blood passes into the left ventricle, and from this into the aorta, by which it is largely distributed to the head and upper extremities; a small quantity only passes into the descending aorta. The venous blood from the head and the extremities is returned by the superior vena cava into the right auricle, from which it passes into the right ventricle, and from this into the pulmonary artery; but only a small quantity of blood is distributed to the lungs, because they are solid in the fœtus. The larger quantity of the blood in the pulmonary artery is conveyed by a short vessel, called the *ductus arteriosus*, into the descending aorta, by which a portion of it is distributed to the lower part of the body of the fœtus, while the greater part is returned by two vessels, the *umbilical arteries*, to the placenta. The latter vessels arise from the internal iliac arteries, pass up the sides of the bladder, then continue onward to the umbilicus, and then along the umbilical cord to the placenta.

The peculiarities of the fœtal circulation may be enumerated as follows:

1. The fœtus receives arterial blood from, and returns its venous blood to, the placenta.

2. The major portion of the arterial blood supplied to the fœtus passes first through the liver of the fœtus.

3. There are two currents of blood in the right ventricle —namely, the blood from the inferior vena cava passes through the foramen ovale directly into the left auricle,

whereas the blood from the superior vena cava passes into the right ventricle.

4. The head and upper extremities of the fœtus are supplied with blood from the ascending aorta, into which vessel it passes from the left ventricle.

5. The lower part of the body receives blood from the descending aorta, which vessel receives the greater part of its blood through the ductus arteriosus.

6. The lower extremities receive but a small quantity of blood, because most of the blood in the descending aorta is returned to the placenta by the two umbilical arteries, which arise from the internal iliac arteries.

7. The lungs of the fœtus receive but a small quantity of blood, because the lungs at that period of life are solid, and the venous blood of the fœtus is arterialized in the placenta of the mother.

8. The peculiarities of the structure of the fœtal heart.

The changes in the circulatory system at birth are the following:

1. Immediately after birth the pulmonary circulation is established. the infant breathes as soon as born, and more blood is supplied to the lungs, as it is now arterialized in the lungs of the infant.

2. The foramen ovale closes a few days after birth; the Eustachian valve and annulus ovalis become obliterated.

3. The ductus arteriosus becomes obliterated soon after birth.

4. The ductus venosus also becomes obliterated and finally forms the round ligament of the liver.

5. The umbilical vein contracts into a fibrous band, which is seen, in the adult, passing up to the liver in the fissure for the ductus venosus.

6. The umbilical arteries become partly obliterated; the portions passing up the bladder on each side remain and form the cystic arteries, the remainder forms fibrous bands.

QUESTIONS AND ANSWERS.

SUBJECT.—*The Blood Circulation.*
Lectures XXI.-XXIII. inclusive.

434. Name the organs of the blood circulatory system.
435. Give the location of the heart.
436. Name the cavities of the heart.
437. Name the septa separating the cavities of the heart.
438. Describe the pericardium.
439. What is the endocardium ?
440. Describe the right auricle.
441. Name the openings into the right auricle.
442. What is the fossa ovalis; the annulus ovalis; the Eustachian valve; the coronary valve; the tuberculum Coweri; the musculi pectinati ? Give location of each.
443. Describe the right ventricle.
444. Name the openings into the right ventricle.
445. What are the columnæ carneæ and chordæ tendineæ ? Give location of each.
446. Describe the pulmonary semilunar valves. Describe the tricuspid valve.
447. Describe the left auricle and name the openings into it.
448. Describe the left ventricle and name the openings into it.
449. Describe the mitral valve.
450. Name the valves and the openings which they guard.
451. What is the annulus atrio-ventricularis ?
452. Give the structure of the cardiac muscular fibres.
453. Describe the arrangement of the muscular fibres of (*a*) the auricles, (*b*) the ventricles.
454. Give the blood-supply to the heart substance.
455. Describe the nervous mechanism of the heart.
456. Describe the circulation of the blood through the heart.
457. What do you understand by the words diastole and systole ?

458. Describe in regular order the events which take place during one cardiac impulse.

459. Give the duration of one cardiac impulse.

460. Give the number of heart beats in one minute (*a*) in the adult man, (*b*) in a new-born infant.

461. Give the comparative duration of each of the various phases of a cardiac impulse.

462. Describe the changes which the heart undergoes in form and in position during a cardiac impulse.

463. What do you understand by the apex-beat? How is it produced, and where is it normally perceptible?

464. Give the relative location of the following anatomical structures of the heart: the aortic valve, the pulmonary valve, the mitral valve, the tricuspid valve.

465. Describe the heart-sounds, their character, quality, pitch, duration, the mode of their production, and place where best heard.

466. Describe the structure of the arteries, capillaries, and veins.

467. How is the circulation of the blood in the system maintained?

468. What is meant by blood-pressure?

469. What are the factors of the circulation of the blood in the arteries, capillaries, and veins?

470. What is the rapidity of the flow of blood in the aorta, and what is it in the capillaries?

471. What do you understand by the tonus of the blood-vessels?

472. Describe the nervous mechanism of the blood-vessels.

473. What do you understand by the pulse?

474. What does the pulse indicate?

475. What is the normal pulse rate in the human adult?

476. What is a sphygmograph? Describe Marey's instrument.

477. How is a cardiac pulsation indicated in the sphygmographic tracing?

478. Explain what a sphygmogram indicates.

479. Describe the sphygmographic tracing of the normal radial pulse.

480. Name the more frequent lesions of the valves of the heart.

481. Describe the sphygmographic tracing of the radial pulse in the case of (*a*) aortic regurgitation, (*b*) mitral regurgitation, (*c*) aortic obstruction, (*d*) mitral obstruction, (*e*) loss of elasticity of the arterial walls.

482. What do you understand by an intermittent, a remittent, a dicrotic pulse?

483. Describe the fœtal circulation.

484. Point out the peculiarities of the fœtal circulatory apparatus.

485. Describe the changes which take place in the circulatory apparatus after birth.

486. What is the average rate of the heart-beat in (*a*) the infant, (*b*) the adult, (*c*) old age?

487. Describe the circulation of the blood.

488. What is the physiological cause of blushing?

489. Define systole, diastole.

490. What causes the first sound of the heart?

491. Describe the factors which cause the heart-sounds.

492. How do the movements of the chest in respiration influence the circulation?

493. Give the shortest course a drop of blood can take in passing from the left to the right ventricle of the heart in normal circulation.

494. What effect is produced on the heart's action by stimulation of the cardiac inhibitory centre?

495. Describe the systole and diastole and their causes.

496. Describe the topography of the normal heart in an adult male.

LECTURE XXIV.

RESPIRATION.

By the word respiration is generally meant the rhythmical and alternate drawing in and forcing out of the lungs of a quantity of air. Respiration has for its object the introduction into the body of the oxygen required for the process of combustion, and the elimination of the carbon dioxide formed in the body. Respiration is effected by the respiratory apparatus, which consists essentially of a moist, permeable membrane which is in contact with the external air on one side and with the blood on the other.

The structure of the respiratory apparatus differs in the several classes of animals, and is adapted to the mode of life and the activity of the individual.

The respiratory apparatus of man consists of the *air-passages* and the *lungs;* the skin must also be considered an important respiratory organ, as through it a constant exchange of gases takes place.

The Air-Passages.

The nasal cavities, the larynx, trachea, and the bronchi are the organs of the respiratory system through which the air passes which is inhaled or exhaled.

The mouth, the nasal cavities and their turbinated bones, and the antrum of Highmore on each side, communicating with the nasal fossæ, present large vascular mucous surfaces over which the cold air passes before it enters the lungs.

The Larynx.

The larynx is that portion of the respiratory apparatus

which is situated in the neck in front of the pharynx and above the trachea; it is composed of nine cartilages, which are so held together by ligaments as to form a firm box for the purpose of protecting its interior structures which constitute the organ of voice. A number of muscles are attached to the larynx, which effect the movements of the organ and its various parts as required for the production of voice.

The larynx is supplied with nerves and blood-vessels. Its interior forms a triangular cavity, broad and wide above, round and narrow below, lined with mucous membrane. It contains the *vocal cords*, and communicates with the mouth and pharynx above and with the trachea below. I will give a fuller description of the larynx when speaking of it as the organ of voice.

The Trachea.

The trachea is that portion of the air-passages which is commonly called the wind-pipe. It is about 4½ inches long, and extends from the lower end of the larynx, through the neck, into the thoracic cavity between the pleuræ and in front of the œsophagus to a point opposite the fourth or fifth dorsal vertebra, where it bifurcates into the two bronchi, one for each lung.

The trachea is tubular. It is composed of a number of cartilaginous rings which are imperfect behind and which are connected with each other by a fibrous membrane; outside of this is a layer of transverse and longitudinal muscular fibres of the non-striated variety. The interior of the trachea is lined with mucous membrane, which is covered with a single layer of columnar ciliated epithelium; between these are the openings of numerous so-called *tracheal glands*, the secretion of which serves to moisten the mucous surface; beneath the latter is a thin layer of elastic fibres.

The cartilaginous rings serve to maintain the lumen of

the tube; they are cylindrical and from three-fourths to one inch in diameter.

The Bronchi.

The trachea bifurcates in the thoracic cavity, opposite the fifth dorsal vertebra, into the right and left bronchi. The *right* bronchus is about 1 inch long and enters the right lung opposite the fifth dorsal vertebra. The left *bronchus* is about two inches long and enters the left lung at a point opposite the sixth dorsal vertebra.

In the lung substance the bronchi ramify freely, constantly diminishing in size, until in the lobules of the lungs they attain a size of 0.4 to 0.5 millimetre—*i.e.*, one-fiftieth to one-thirtieth of an inch—in diameter, and finally open into the pouch-like expansions known as the *infundibula.* The smaller bronchi are called *bronchioli.*

The structure of the bronchi varies with their size. The larger bronchi have the same structure as the trachea; the smaller bronchi do not contain cartilaginous rings, but merely cartilaginous laminæ scattered through their walls, principally at the points of bifurcation. The smallest bronchi do not contain any cartilaginous masses in their walls, but, instead of these, circular muscular fibres. The bronchi all contain a fibrous coat and muscular and elastic fibres; their interior is lined with mucous membrane covered with ciliated epithelium. The mucous membrane of the bronchi is moistened by the tenacious secretion of numerous goblet-cells which are situated between the epithelial cells; this tenacious secretion also serves to retain particles of dust which are inhaled with the air.

The Lungs.

The principal organs of the respiratory apparatus—namely, the two lungs—lie in the lateral portions of the thoracic cavity.

Each lung is surrounded by a closed sac of serous membrane, called the *pleura.* This consists of a *parietal* and a

visceral layer, and serves to prevent friction between the lung and its parietes. The pleuræ are attached to the structures which comprise the root of the lungs. Each lung is conical in shape, with its base directed downward. The *apex* is pointed and extends about 1 inch above the first rib. The *base* is concave and rests upon the diaphragm. The *exterior* surface of the lungs is convex and is directed toward the inner surface of the chest-walls anteriorly, laterally, and posteriorly. The *inner* surface is concave and is directed toward the middle line. The space between the two lungs is termed the *mediastinum.*

Each lung is divided by a transverse fissure into an *upper* and a *lower* lobe. The upper lobe of the right lung is generally divided by a second fissure, so that this lung consists of three lobes. Various structures—namely, the pulmonary artery and veins, the bronchial artery and veins, nerves, lymphatics, and one bronchus—enter and leave the lung at its inner surface a little above the centre. These structures are surrounded by areolar tissue and constitute the root of the lung.

The lungs receive blood through two vessels. The *bronchial artery* conveys to the lung the blood intended for its *nutrition.* The vessel enters the lung at its root, and in its course through the lung follows the ramifications of the bronchi and bronchioles, distributing numerous branches to the walls of these and to the different structures composing the lungs. The *bronchial veins* return the venous blood from the lungs and leave them at the roots. The *pulmonary artery* carries venous blood from the heart to the lungs. The artery enters the lung at its root; in its course it follows the ramifications of the bronchial tubes, and finally divides into a capillary plexus which is distributed to the walls of the air-cells; here the blood takes up oxygen from the air, and is returned by the *pulmonary veins* as arterial blood to the heart.

The *lymph-vessels* of the lungs begin as minute channels

in the walls of the air-cells. The vessels follow the course of the bronchi and leave at the root of the lung.

The nerves supplying the lung-structures are derived from the pulmonary plexus, which is formed by fibres from the sympathetic and pneumogastric nerves.

The weight of both lungs is about 42 ounces, or 1,340 grammes. The right lung is about two ounces heavier than the left.

To the touch the lungs feel spongy, and crepitate when handled, owing to the pressure of air in them. Lung-tissue has a specific gravity of 0.345 to 0.745, and consequently floats on water.

The color of the lungs is pinkish-white in childhood, but becomes slate-colored and spotted in adult life; this discoloration, which advances with age, is due to the deposition of particles of carbonaceous matter.

The relative extent of the lungs in the thoracic cavity can be determined by percussion and by auscultation—methods in which you will receive practical instruction.

The Structure of Lung-Tissue.

Each lung is externally covered by a serous membrane, the visceral layer of the pleura; beneath this is a fibrous coat which contains elastic fibres, and which sends prolongations into the substance of the lung, dividing it into numerous small masses called lobules.

The *lobules* of the lungs are small, polyhedral masses of lung-tissue; they are connected by interlobular areolar tissue. A lobule consists of a *terminal bronchus*, which expands into a pouch called the *infundibulum;* this has numerous sacculated recesses, which are called the *air-vesicles, alveoli*, or *air-cells.*

The walls of the infundibula and their alveoli are composed of fibrous tissue containing elastic and non-striated muscular fibres, and support the capillary plexus of the pulmonary artery. The interior of the infundibula is lined

with the same epithelial cells which cover the lining of the terminal bronchioles: the alveoli, air-vesicles, or air-cells are lined with a layer of flat, many-sided epithelial cells. The exchange between the gases of the blood in the capillaries and those of the inhaled air takes place through the walls of the alveoli.

The total number of such air-cells or alveoli in the human lungs has been estimated to be 809,500,000, and their total respiratory surface to be 81 square metres.

The Mechanism of Respiration.

The respiratory act consists of an inspiration and an expiration of air.

Inspiration is the aspiration of air into the air-passages and lungs; it is effected by an expansion of the thoracic cavity in its several diameters; and the lungs, which, with their outer surfaces, are in close contact with the internal surface of the chest-wall, will follow any expansion of the chest, owing to their elasticity. The expansion of the lungs causes a decrease in the density of the air contained in them, and consequently air will rush into the lungs through the air passages until the density of the air in the lungs has become equal to the density of the external air.

The expansion of the chest is a muscular act; the vertical diameter of the thoracic cavity is increased by the descent of the diaphragm; the horizontal—viz., the antero-posterior and lateral—diameters are increased by the raising of the ribs and sternum. The ordinary position of the ribs is obliquely downward and forward from their spinal to their sternal articulation; during inspiration the ribs are raised and with them the sternum.

The muscles used during an *ordinary* inspiration are: the external intercostal muscles, the scaleni, the levatores costarum, the serratus posticus superior, and the diaphragm.

During a forced *inspiration* the following muscles are

used: the pectoralis major and minor, the serratus magnus anticus, the trapezius, and the muscles of the neck.

Expiration is the act by which air is forced out of the lungs through the air-passages; it is effected by the retraction of the chest-walls and consequent retraction of the lungs. During inspiration the ligaments and soft parts of the chest-walls are stretched, and the force which they exert when they return to their normal state, together with the weight of the chest-walls and the cessation of the contraction of the muscles used during inspiration, is sufficient to effect an *ordinary expiration*, during which the diameters of the chest-cavity are decreased by the retraction of the chest-walls and the ascent of the diaphragm.

By an effort of the will the thorax may be still more retracted than it is by an *ordinary expiration*, and a still greater quantity of air can be forced out of the lungs.

The muscles used in such a *forced expiration* are: the internal intercostal muscles, the serratus posticus inferior, the quadratus lumborum, the latissimus dorsi, and the abdominal muscles.

The respiratory movements present characteristic types in men, women, and children. It will be observed that in men the lower part of the chest is more expanded than the upper; this is termed the *inferior costal type*. In women the upper part is most expanded; this is called the *superior costal type*. In children the respiratory movements are largely effected by the motions of the diaphragm, as may be seen by the peculiar up-and-down motion of the abdomen; this peculiarity is described as the *abdominal type*.

The adult human individual inhales and exhales at each inspiration and expiration about 30 cubic inches, or 500 cubic centimetres, of air; this quantity is called the *tidal* or *breathing air*. The same individual is capable of inhaling by a forced inspiration 100 cubic inches, or 1,600 cubic centimetres, of air, in addition to the 30 cubic inches already taken in during the ordinary inspiration. The 100 cubic

inches of air so taken in by a forced inspiration are called the *complemental air.*

After an ordinary expiration a quantity of 100 cubic inches of air can be forced out of the lungs by a forced expiration ; this is called the *reserve air.*

After the most forcible expiration there remain in the lungs 100 cubic inches of air, which is known as the *residual air.*

The *total* air-capacity of the lungs is therefore 330 cubic inches, or 5,200 cubic centimetres—namely, 100 cubic inches of residual air, 100 cubic centimetres of reserve air, 30 cubic centimetres of tidal air, and 100 cubic centimetres of complemental air.

The *breathing capacity* is the quantity of air which can be exhaled after the lungs have been filled by a forced inspiration. This amount is 230 cubic inches—namely, 30 cubic centimetres of tidal air, 100 cubic centimetres of complemental air which was taken in by the forced inspiration, and 100 cubic centimetres of reserve air which, in addition to the tidal and complemental air, can be expelled from the lungs by a forced expiration.

The quantity of air which is exhaled or inhaled by an individual is measured by an instrument called the spirometer. The instrument consists of an air-reservoir suspended over water. The reservoir communicates by means of a tube with the inhaler into which the individual breathes. The quantity of air forced into the reservoir, or the quantity taken out of the same, by the inspiration and expiration, is indicated on a scale which communicates with the air-reservoir.

The number of respirations in the adult are 14 to 18 a minute, which is about 1 respiration to 4 cardiac pulsations. The number of respirations is increased by exercise, and generally in all those conditions in which the cardiac pulsations are increased. In children respiration is more frequent than it is in adults. In febrile conditions the

respirations are increased in number proportionally with the increase of the cardiac pulsations. In many pulmonary diseases the number is often greatly increased.

The quantity of air required by a healthy adult for respiration in twenty-four hours is about 2,150 cubic feet—that is, at the rate of from 16 to 18 respirations per minute. During that time the individual consumes 900 grammes of oxygen and exhales 744 grammes of CO_2 and about 500 grammes of water in the form of watery vapor.

LECTURE XXV.

THE ATMOSPHERIC AIR AND THE CHANGES WHICH IT UNDERGOES DURING RESPIRATION.

THE atmospheric air which we breathe is a mixture of gases containing 20.92 per cent of oxygen, 79.03 per cent of nitrogen, and 0.03 to 0.05 per cent of carbon dioxide. Besides these the atmospheric air contains at all times a greater or less quantity of watery vapor. This quantity differs; it is influenced by the location, temperature, season, geographical conditions, and the time of day.

The quantity of watery vapor in the atmosphere is measured by means of the *hygrometer*. It will be found to be greater in valleys than on mountains; is greater in winter than in summer; greater when south and west winds prevail than when east and north winds blow; and it is greater in the morning until sunrise, and least at noon, increasing again toward evening and during the night.

Atmospheric air often contains impurities, such as traces of ammonia, sulphuretted hydrogen, dust, etc. Besides these more common impurities the atmospheric air sometimes contains substances which are injurious to the health of the individual breathing the air. Among these impurities we may mention the poisonous and irrespirable gases, pathogenetic substances, etc.

The *temperature* of the atmospheric air is generally lower than that of the air in the lungs.

During respiration the air undergoes certain changes, which may be enumerated as follows :

1. The quantity of oxygen is diminished.
2. The quantity of carbon dioxide is increased.

3. The volume is diminished.
4. The watery vapor is increased.
5. The temperature is increased.
6. A small quantity of ammonia and organic matter is added.

Respiration consists of three distinct phases:

1. The inspiration and exhalation of the air.
2. The exchange of a quantity of CO_2 in the blood of the capillary plexus distributed to the walls of the air-cells of the lungs, for a quantity of oxygen from the air contained in the alveoli or air-cells. This exchange of gases is termed the *external respiration*, and it takes place through the walls of the capillaries and of the air-cells.
3. The exchange of the CO_2 formed in the tissues as a product of combustion, for a quantity of oxygen from the blood contained in the capillaries distributed to the tissues. This exchange of gases is termed the *internal respiration;* it takes place through the walls of the capillaries. This exchange of gases is due to the physical processes known as the diffusion and dissociation of gases.

The *diffusion* of gases is a phenomenon which is observed to take place between the particles of gases which do not combine chemically. When such gases come together their particles will tend to mix until an equal mixture is obtained. This diffusion takes place independently of the specific weights of the gases, and it also takes place through the pores of an animal membrane.

The *dissociation* of gases is a phenomenon where certain gases will, under a certain pressure, unite chemically with other substances, and where the chemical union so produced will dissolve again when the pressure required for its formation is decreased to a certain extent. This phenomenon, according to *Donders*, plays an important rôle in the respiratory exchange of the gases.

If the air in the various portions of the respiratory apparatus is examined, it will be found that the air in the

alveoli of the lungs contains a greater percentage of CO_2 and a smaller percentage of oxygen than the air in the smaller bronchi, and that the air in these contains also a smaller percentage of oxygen and a larger percentage of CO_2 than the air in the larger bronchi, and it will also be found that the air in the upper air-passages becomes more and more similar to the ordinary atmosphere, as regards its percentage of CO_2 and oxygen; so that it may be said that the air in the various portions of the respiratory tract consists, as it were, of layers in which the percentage of CO_2 and oxygen differs. The result is a continual diffusion of gases in the air-passages, the oxygen passing toward the lower, and the CO_2 passing toward the upper, parts of the same, with the tendency to produce an equal mixture of the gases in all parts of the respiratory tract.

The exchange of the CO_2 in the blood of the capillaries distributed to the walls of the alveoli, for a quantity of oxygen from the air contained in the alveoli, and the exchange of the CO_2 formed in the tissues for a quantity of the oxygen contained in the blood of the capillaries supplying the tissues, is caused principally by the difference in the tension of these gases.

Carbon dioxide is produced continually in the tissues as the result of combustion. The tension or pressure of this gas in the tissues is greater than the tension of this gas contained in the blood of the capillaries anastomosing in the tissues; the result is that, owing to this greater pressure, CO_2 is taken up by the blood and forms chemical compounds with its ingredients.

The blood which contains the CO_2 so taken up is conveyed to the lungs, and here the CO_2 is liberated from its compounds, because the tension of this gas in the air in the alveoli of the lungs is much less than it is in the compounds contained in the blood of the capillaries supplying the walls of the alveoli, and the result is that the so liberated CO_2 passes from the blood toward the air in the alveoli,

owing to the law of diffusion of gases. Arterial blood contains about 30 per cent, venous blood from 35 to 50 per cent, of CO_2 by volume. A small portion of the CO_2 is contained in simple solution in the plasma; the greatest portion is contained in chemical combination with the sodium of the plasma and with ingredients of the blood-corpuscles.

Oxygen is constantly required for the process of combustion in the tissues of the body: it is taken up by the blood contained in the capillaries supplying the walls of the alveoli, from the air contained in these, because the tension or pressure of the oxygen in the air filling the alveoli is much greater than the pressure of this gas in the blood of the capillaries of the walls of the alveoli.

Again, the oxygen contained in the blood of the capillaries ramifying in the tissues passes toward these, because the tension of this gas in the tissues is much less than it is in the blood of the capillaries anastomosing in the tissues.

Oxygen is contained in the blood partly in a simple solution in the plasma, but to a greater extent in chemical combination with the HO of the red blood-corpuscles.

The exchange of the gases of the atmosphere with those of the air in the alveoli of the lungs, and of the oxygen of the air in the alveoli for CO_2 in the pulmonary capillaries, and, lastly, the exchange of the oxygen in the capillaries of the tissues for the CO_2 formed in these, is caused mainly by the difference in the tension of these gases in the atmosphere, in the air of the alveoli, in the arterial and venous blood, and in the tissues.

Experiments made to ascertain the difference in the tension of these gases have given the following approximate results:

The *tension of the oxygen* in (*a*) the atmospheric air is equal to 158 millimetres Hg; (*b*) in the air of the alveoli, 27.4 millimetres Hg; (*c*) in the venous blood, 22 millimetres Hg; (*d*) in the arterial blood, 29.6 millimetres Hg: it is

lowest in the tissues. The tension of the CO_2 in (*a*) the atmospheric air is equal to 0.038 millimetre Hg; (*b*) in the air of the alveoli of the lungs, 27 millimetres Hg; (*c*) in the venous blood, 41 millimetres Hg; (*d*) in arterial blood, 21 millimetres Hg; it is highest in the tissues.

Expired air shows a decrease of oxygen. Inspired air normally contains 20.92 per cent of oxygen by volume; expired air, 16.14 per cent. The balance is taken up by the blood; it is equal to 4.78 per cent of the volume of the inspired air. The total weight of the quantity of oxygen consumed by the healthy adult man in twenty four hours is estimated to be 900 grammes.

Expired air shows an increase of CO_2, due to the elimination of CO_2 from the blood in the pulmonary capillaries. The total weight of the CO_2 eliminated from the body by the healthy adult man in twenty-four hours is estimated to be 744 grammes.

This exchange of these two gases is in a certain proportion, so that for every volume of oxygen which is taken up into the blood a little less than an equal volume of CO_2 is given off from the blood. Atmospheric air contains 0.03 to 0.05 per cent of carbon dioxide; expired air contains about 4.38 per cent of this gas in volume.

This shows that the volume of CO_2 which is replaced for the oxygen in the air during respiration is about one-fortieth smaller than the volume of oxygen given off.

The result is a corresponding decrease in the volume of air during the respiration. This decrease in the volume of the expired air, as compared with that of the inspired air, is only perceptible when the temperature and the percentage of moisture in the expired air are the same as those of the inspired air. The volume of the expired air is really greater than that of the inspired air, but this is due to the increase of the temperature and watery vapor in the expired air.

The watery vapor of the air is generally increased during

respiration. The degree of increase depends, first, upon the quantity of watery vapor contained in the atmosphere; second, upon the temperature of the expired air; and, third, upon the length of time the inspired air is retained in the lungs. The watery vapor which is exhaled is produced by the evaporation of the water secreted from the blood by the pulmonary mucous membrane. The quantity of watery vapor exhaled is generally the quantity which is required to saturate the expired air. If, therefore, the inspired air already contains a large percentage, then but little more is required to saturate it, and *vice versa.* If the inspired air is retained in the lungs for a longer time its temperature is raised ; the result is a corresponding effective evaporation of moisture from the pulmonary mucous membrane, and a resulting increase of watery vapor in the expired air. It has been estimated that the quantity of water thus eliminated from the body in twenty-four hours is about 500 grammes.

The temperature of the air is generally increased during respiration to such an extent that expired air assumes the temperature of the blood—viz., 98° to 99° F. It has been observed that when the temperature of the inspired air is higher than that of the blood there is a decrease in the temperature during respiration.

An examination of the expired air, as compared with the inspired air, shows an increase of organic matter and of free ammonia. It is estimated that the quantity of ammonia exhaled with the air is about 0.02 gramme in twenty-four hours.

LECTURE XXVI.

THE NERVOUS MECHANISM OF RESPIRATION.

THE act of respiration is induced and regulated by the activity of a centre which is known as the *centre of respiration;* this is located in the floor of the fourth ventricle of the brain. It is an *automatic* centre; its activity is ordinarily not induced by stimuli received through peripheral nerves.

The *centripetal* nerves—that is, the nerves by which the impulse for the respiratory movements is conducted from the centre to the periphery—are the motor nerves of the muscles concerned in the respiratory movements.

Respiration is to a limited extent under the control of the will. The centre of respiration is also irritated by stimuli received through peripheral nerves, such as the sensory nerves of the air-passages and lungs; the respiratory movements so produced are essentially a reflex act.

Ordinarily the normal automatic activity of the centre of respiration depends upon the normal quantity of oxygen in the blood of the brain.

The normal condition of respiration is described as *eupnœa;* in this condition the respirations are free, easy, and regular.

When the quantity of oxygen in the blood of the brain is abnormally *increased*, then the centre of respiration is influenced in such a manner that the respiratory motions become slower; they become difficult and the expiration is forcible; this condition is known as *apnœa*.

When the quantity of the oxygen in the blood of the brain is abnormally *decreased*, then the centre of respira-

tion is influenced in such a manner that the respiratory motions become hurried, labored, and difficult, and inspiration is more forcible; this condition is called *dyspnœa*. Such difficult breathing is observed, for instance, at high temperatures; this is due to the greater and more rapid consumption of oxygen in the tissues and its consequent decrease in the blood. Prolonged dyspnœa is generally accompanied by *cyanosis*, *i.e.*, a bluish discoloration of the skin and mucous membranes; this is due to the decrease of oxygen in the blood. When, by an obstruction of the air-passages, the air is hindered from entering the lungs, or when a gas containing no free oxygen is inhaled instead of air, then a condition is produced which is known as *suffocation;* during this the respiratory movements are labored, then there is a spasmodic contraction of the muscles of respiration, and finally the respiratory movements cease entirely, the skin and mucous membranes become dark, almost black, and death occurs by *asphyxia*, which is a want of oxygen.

When the quantity of carbon dioxide in the blood is abnormally increased there will also be dyspnœa, but in this condition the *expirations* are more forcible, whereas in the dyspnœa produced by a decrease of oxygen in the blood the *inspirations* are more forcible.

The pneumogastric nerves contain fibres which are distributed to the lungs. When the pneumogastric nerves are cut in the neck, then the respiratory motions become slower, deeper, and less regular. When the central stump of the pneumogastric is stimulated by an interrupted current, the respiratory motions will become quicker and more regular, and, by a proper application of the current, the normal rhythm and character of the respiratory movements can be produced. These experiments tend to demonstrate that the normal activity of the centre of respiration is to a certain extent regulated by stimuli which, from the lungs, are conducted to the centre by the pulmonary

fibres of the pneumogastric nerve. The irritation of certain peripheral sensory nerves influences the respiratory movements. Certain special respiratory acts, such as coughing, sneezing, sighing, and yawning, are reflex, being caused by the irritation of certain sensory nerves. *Coughing*, for instance, is produced by an irritation of the sensory nerve of the larynx—namely, the superior laryngeal nerve, by which the stimulus is conducted to the centre; the result is a closure of the glottis and a sudden, forcible expiration accompanied by the peculiar sound heard when coughing.

Irritation of the sensory nerves of the skin of the head, neck, and chest—for instance, the application of cold water—produces deep and forcible respiratory movements as the result of the stimulation of the centre of respiration by stimuli received through peripheral sensory nerves.

From this description of the function of respiration you will learn that the sole purpose of this function is to maintain the proper exchange of the gases of the blood—namely, of the carbon dioxide which is constantly formed in the body as the result of the combustion of substances, for the quantity of oxygen from the inspired air which is required for this process of combustion. Respiration, like the whole physiological activity of the organism, depends upon the proper exchange of these gases; this is best shown by the serious functional disturbances caused by any interference with this normal exchange of gas.

To maintain a normal activity of the respiratory function and a proper exchange of the gases in the blood, it is not only essential that the respiratory apparatus be in a normal condition, but also that the atmosphere we breathe be normal in *quantity*, *quality*, and *condition*.

It is essential (1) that we breathe air or a mixture of gases which contains *oxygen* in proper quantity and in a form which does not prevent its being taken up by the blood.

(2) That the mixture of gases we breathe should not

interfere with the elimination of carbon dioxide from the blood.

(3) That the pressure which the atmosphere exerts upon the surfaces of the body be within certain limits.

To understand this more fully I will describe to you the effects produced when these conditions are changed.

Oxygen is the essential ingredient of air. If the mixture of gases we breathe contains no oxygen, death from suffocation quickly takes place, even if the mixture of the gases breathed does not interfere with the elimination of CO_2. Normal atmospheric air contains 20.92 per cent of oxygen by volume; expired air still contains 16.14 per cent of this gas; if this percentage is even decreased to 9 per cent no special influence on respiration is produced; when decreased to 8 per cent great inconvenience is experienced; at 7 per cent dyspnœa is caused; and when reduced to 3 per cent death results in a short time from want of oxygen.

A decrease in the quantity of oxygen in the atmosphere causes its decrease in the blood, owing to the decreased tension of this gas in the air contained in the alveoli of the lungs. The dyspnœa produced by this condition is due to the influence on the centre of respiration. An increase of oxygen in the atmosphere has no effect on respiration and causes but a small increase of oxygen in the blood.

Carbon dioxide (CO_2) is contained in atmospheric air only in a very small quantity—viz., about 0.03 to 0.05 per cent. The gas is constantly produced in the body and exhaled with the expired air. Breathing in a closed room brings about a decrease of the oxygen in the air; CO_2 is constantly increased, and the volume of the atmosphere in the room is decreased. If the CO_2 in the atmosphere is present to such an extent that its tension in the atmosphere is greater than in the blood, then the CO_2 elimination from the blood ceases; in fact, CO_2 re-enters the blood and dyspnœa and rapid death are the result.

The dyspnœa produced by such accumulation of CO_2 in

the blood differs from that produced by a diminution of the oxygen, in that it is short and not accompanied by muscular spasms and convulsions, and in that all respiratory motions soon cease. Breathing in a small, closed room uses up the oxygen before sufficient CO_2 has accumulated in the atmosphere to prevent its elimination from the blood; the result is that dyspnœa and suffocation are produced by want of oxygen in the blood. Breathing in a large, closed room causes the accumulation of CO_2 in a sufficient amount to bring about dyspnœa and death before the quantity of oxygen is sufficient to interfere with the respiration.

The *nitrogen* of the air is an indifferent gas—that is, one which has no effect on respiration and does not interfere with the exchange of oxygen and carbon dioxide; it may be replaced by any other indifferent gas, such as hydrogen, without producing any marked effect on respiration. The presence of *irrespirable* or of *poisonous* gases in the air, or the breathing of such, seriously interferes with respiration and the subsequent exchange of the gases of the blood. *Irrespirable* gases are those which irritate the mucous membrane of the respiratory tract and so cause abnormal respiratory motions; such gases are bromine, chlorine, fluorine, etc.

Poisonous gases are those which produce chemical changes in the blood ingredients and so interfere with the taking of oxygen or the elimination of CO_2; such gases are carbonic oxide (CO), cyanic acid, hydrogen sulphide, etc. They deoxidize the HO of the red blood-corpuscles, with which they unite chemically, and thus prevent the taking up of oxygen.

Nitrous oxide (N_2O), or *laughing gas*, is a gaseous compound which is frequently used in dental practice to produce general narcosis; the narcosis is of short duration and is produced by the effect of the gas on the nervous system. Air containing *ozone* in large quantities has a similar effect.

Both of these gases are known as *narcotizing* gases; they do not interfere with respiration.

The atmosphere often contains impurities which are injurious; such impurities are dust, exhaled organic matter, micro-organisms such as germs of disease—as, for instance, of diphtheria, pneumonia, influenza, tuberculosis, malarial diseases, pertussis, etc. Rooms occupied by many individuals, such as school-rooms, factory-rooms, hospital-wards, etc., are often filled with air which is contaminated with impurities and in which the percentage of CO_2 is unduly large; to prevent such conditions it is necessary that these rooms be thoroughly ventilated to admit fresh air.

The air surrounding all bodies exerts an even pressure upon the free surfaces, owing to its weight; this is called the *atmospheric pressure;* it is measured by the use of the instrument known as the *barometer*. This, in its simplest form, consists essentially of a box which communicates with a glass tube; this and the box are partially filled with mercury. The space above the column of mercury in the glass tube is a vacuum. The pressure of the atmosphere upon the surface of the mercury in the box forces the column of mercury in the glass tube upward; any variations in the atmospheric pressure are indicated by a rise or fall of this mercurial column. The glass tube is graduated into millimetres or inches, and the atmospheric pressure is said to be so many millimetres or inches Hg, according to the mark at which the mercurial column in the glass tube of the barometer stands.

The average atmospheric pressure at the level of the sea and at 60° F. is 760 millimetres or 30 inches Hg. Minor variations are produced by changes in the temperature and in the degree of humidity of the air; an increase of these produces an increase of the atmospheric pressure.

These minor variations of the atmospheric pressure have no marked effect on the respiration, whereas greater variations produce serious disturbances, not only of the respi-

ration and the exchange of gases, but also of the circulation and other vital functions.

A great increase of the normal atmospheric pressure has the following effect :

The respirations become slower, easier, and less deep; the skin is pale and dry; the secretions from the skin and mucous surfaces are diminished; speech is difficult and the voice is changed; the hearing is sharp, but there is pain owing to the pressure on the membrana tympani. The quantity of oxygen in the blood is increased, oxidation is more active, and the consequent production of CO_2 is increased; the elimination of CO_2 from the body is not interfered with ; there is congestion of the internal viscera. These phenomena are often observed in people working under water.

A great decrease of the normal atmospheric pressure has the reverse effect. The skin and mucous surfaces become red and swollen, owing to the decrease of the pressure upon them. The secretions of the skin and mucous surfaces are increased ; often there is hemorrhage from the mucous surfaces. The congestion of the surfaces of the body produces anæmia of the internal organs. The limbs become heavier, because the muscles alone must hold the ball and socket joints in place, while under normal conditions the atmospheric pressure plays an important rôle in this. The respirations become quicker and more difficult ; inspiration especially is labored ; the quantity of the oxygen in the blood is decreased ; the voice is altered, hearing difficult ; there is pain owing to the pressing out of the tympanum. When the atmospheric pressure is decreased to 240 millimetres Hg, death occurs under the symptoms mentioned. Aeronauts have ascended in balloons to a height of 8,600 metres and found the atmospheric pressure to be 280 millimetres Hg.

Before finishing this subject I will speak of the respiratory function of the skin.

It has been demonstrated by experiments that through the skin there takes place a constant elimination of CO_2 and the taking up of an equal volume of oxygen. However, the respiratory activity of the skin is very small as compared with that of the respiratory apparatus.

QUESTIONS AND EXERCISES.

SUBJECT.—*The Respiration.*
Lectures XXIV.-XXVI. inclusive.

497. What is meant by respiration?
498. Name the organs composing the respiratory apparatus in man.
499. What are the pleuræ? Describe them.
500. Give a short description of the larynx.
501. Describe the trachea.
502. Describe the structure of the bronchi, and point out the differences in the structure of the larger, the smaller, and the smallest bronchi.
503. Give a short description of the cross anatomy of the lungs.
504. Name the structures composing the root of a lung.
505. Describe the structure of lung-tissue.
506. Describe the circulation of the blood in the lungs.
507. Why does the normal lung-tissue float on water?
508. What do you understand by external and what by internal respiration?
509. Give the composition of the atmosphere.
510. Name the impurities in the atmosphere.
511. What is tidal air? complemental air? reserve air? Give the quantity of each.
512. What is the air capacity of the lungs, and what is the respiratory capacity?
513. Give the number of respirations per minute.

514. What are the changes which air undergoes during respiration?

515. What do you understand by the diffusion and what by the dissociation of gases?

516. What is the main factor in the respiratory exchange of the gases oxygen and carbon dioxide? Explain.

517. What is the tension of the oxygen in the atmosphere? in the air of the alveoli? in the blood of the pulmonary capillaries? in arterial blood? and how does its tension in these compare with its tension in the tissues?

518. What is the tension of the carbon dioxide in the atmosphere? in the air of the alveoli? in venous blood? in arterial blood? and how does its tension in these compare with its tension in the tissues?

519. How are an ordinary inspiration and an ordinary expiration effected, and what muscles are used in these acts?

520. How are a forced inspiration and a forced expiration effected, and what muscles are used in these acts?

521. Describe the nervous mechanism of respiration.

522. How is the centre of respiration affected by an increase of the oxygen in the blood, and how by a decrease?

523. What is the effect on the respiratory motions?

524. Define eupnœa, dypsnœa, apnœa, suffocation, asphyxia.

525. What is the minimum percentage of oxygen which a volume of air must contain in order to support life? What would be the effect produced by decreasing this percentage?

526. At what percentage of the CO_2 in a volume of air would CO_2 poisoning be produced? Describe the symptoms.

527. What is the difference in the symptoms produced by a want of oxygen in the blood and those produced by an accumulation of CO_2?

528. What is meant by atmospheric pressure?

529. What is the pressure of the atmosphere at the level of the sea and at 60° F.?

530. What causes the common minor deviations of atmospheric pressure?

531. What are the effects produced by a great increase and those produced by a great decrease of the atmospheric pressure? Explain.

532. Why is the effective ventilation of rooms essential for the welfare of the individuals occupying them?

533. What would be the result caused by breathing in a small, closed room, and what the result by breathing in a large, closed room?

534. What is the total quantity of oxygen, by weight, consumed by a healthy human adult in twenty-four hours?

535. What is the total quantity of CO_2, by weight, eliminated by a healthy human adult in twenty-four hours?

536. How do the number of respirations compare with the frequency of the pulse?

537. Explain in short how coughing, sneezing, yawning, and laughing are produced.

538. What muscles are engaged in ordinary inspiration? What muscles are involved in extraordinary or forced expiration?

539. What post-mortem test should be applied to prove that air had entered the lungs of a supposedly stillborn child?

540. Define the functions of the mucous membrane of the respiratory tract.

541. Where is the respiratory centre?

542. How much air is required for normal respiration during twenty-four hours?

543. State the changes in the diameter of the chest in inspiration and in expiration.

544. Give the physiology and the mechanism of respiration.

545. Explain the process of expiration.

546. Where and how is the blood changed from arterial to venous? From venous to arterial?

547. What effect has respiration on the blood?

548. Describe in full a normal respiration.

549. Give the causes of perverted function producing dyspnœa and asphyxia.

550. How much oxygen is abstracted by respiration from every volume of air inhaled?

551. What is the object of respiration?

552. Is respiration purely a voluntary act? Explain.

LECTURE XXVII.

ASSIMILATION.

By the term assimilation is meant the transformation of the absorbed nutritive materials into the chemical ingredients of the body. These transformations consist of chemical. probably synthetical, changes; the highest product of these processes is the living protoplasm of the cells. The development, growth, and regeneration of the tissues of the body are the results of the constant assimilative changes of the nutritious materials absorbed in the circulation.

The first substances formed as the result of these processes are the ingredients of the blood and lymph, from which, by further assimilative changes, the various ingredients of the tissues are formed.

The ingredients of the blood are partly taken up as such during absorption—for instance, the water and the salts. The specific ingredients of the blood—namely, the blood-corpuscles—are formed in certain organs as the product of assimilative changes which certain materials of the blood undergo in these organs.

The *erythrocytes* are formed, in post-embryonal life, in the red marrow of the bones. The latter consists of a delicate network of adenoid tissue, which is freely permeated by a capillary network and which contains lymphoid corpuscles; in it are also seen rounded, nucleated cells which contain a reddish protoplasm. After a great loss of blood numerous such cells are seen in the blood; they are called *erythroblasts*, and it is believed that they originate from the lymphoid cells of the red marrow of the bones.

The hæmoglobin in these new-formed erythrocytes is the product of assimilative changes in the protoplasm of the lymphoid cells. In the embryo the erythrocytes originate in a similar manner in the liver from the leucocytes conveyed to the liver with the blood of the splenic vein.

The *leucocytes* originate in the spleen and in the lymphatic glands. The *spleen* is called the vascular gland, because a large amount of blood is contained in its substance, and because its main function is to produce blood-ingredients—namely, white blood-corpuscles. The spleen is situated in the left hypochondrium beneath the diaphragm; its exterior surface is oval, its inner portion concave and is called the *hilus*, at which vessels and nerves enter and leave the organ.

The structure of the spleen is similar to that of the lymphatic glands. It has an external peritoneal covering; beneath this is a fibrous layer which contains elastic and non-striated muscular fibres; this is called the *capsule*. From it prolongations pass throughout the organ, which in their course surround the structures which enter and leave at the hilus. Other prolongations from this fibrous capsule pass into the substance of the organ; they are called *trabeculæ*, and divide the organ into numerous compartments. These fibrous structures constitute the *stroma* of the organ, and in its meshes are found the structures which constitute the pulp of the spleen.

The *spleen-pulp* is of a dark-reddish color and a brittle consistence; it is composed of branching connective-tissue cells which anastomose with their branches; the interstices between these cells are filled with blood.

The blood-supply to the spleen is through the splenic artery, a comparatively large vessel, which, before entering the organ at the hilus, divides into several branches; these pass along and are supported by the fibrous trabeculæ in the organ, until after a short course they divide into bundles of straight arterioles called *penicilli*, which pene-

trate the organ in all directions. The walls of these arterioles gradually change; their fibrous coat thickens and is transformed into adenoid tissue consisting of a loose reticulum and presenting here and there spheroidal, thickened masses of adenoid or lymphoid tissue which are called *Malpighian* corpuscles; these contain lymphoid corpuscles. The arterioles finally break into a capillary plexus; the capillaries ramify in the pulp of the organ; finally their walls, being composed of lymphoid tissue, become obliterated, are no longer tubular, and their lymphoid cells become branched and anastomose with the branched connective-tissue cells which constitute the spleen-pulp; the blood of the capillaries fills the interstices between these cells. It is probable that here the materials of the blood undergo assimilative changes which result in the production of leucocytes.

The veins of the spleen arise from the interstices between the cells of the spleen-pulp; in their course through the organ they frequently anastomose, and finally they unite to form one vessel, the splenic vein, which leaves at the hilus of the organ and opens into the portal vein. The spleen is also freely supplied with lymphatics and nerve-fibres; the latter are distributed to walls of the blood-vessels and to the non-striated muscular fibres of the organ.

The fact that the spleen is the principal organ for the production of leucocytes is demonstrated by their enormous increase in number in the blood of the splenic vein as compared with their number in the blood of the splenic artery.

In the artery the proportion is 1 white to 60 red; in the vein it is 1 white to 2,200–2,400 red corpuscles. The fact that the lymphatic glands are also organs in which leucocytes are formed is clearly shown by their larger number in the lymph leaving the gland as compared with their number in that entering the gland. In a pathological condition called *leucocythæmia*, which is characterized by an enor-

mous numerical increase of the leucocytes in the body, we often find a considerable swelling of the spleen and the lymphatic glands—a fact which tends to demonstrate the increased physiological activity of the organ. Although we do not fully understand just how and from what materials the leucocytes are formed in these organs, it cannot be doubted that their production is the result of assimilative changes of materials supplied to these organs with the blood.

The origin of the lymph ingredients I have already described in my last lectures.

The liver is to be considered probably as the organ in which the most important assimilative changes take place. All the nutritive materials which are absorbed in the stomach and intestines by the blood-capillaries are conveyed by the portal vein through the liver.

The formation of the bile-pigments and bile-salts in the liver from materials of the blood must be considered as synthetical chemical processes. Furthermore, the *glycogenetic* function of the liver—namely, the property of the cells of that organ to transform materials of the blood into glycogen—is an assimilative function which is of great importance.

Glycogen is also called animal starch; it is a carbohydrate which is isomeric with starch; its chemical formula is $C_6H_{10}O_5$; with iodine it gives a claret-red color.

Glycogen is formed in the liver from the nutritive materials contained in the blood of the portal vein. This is demonstrated by the fact that during the stage of inanition no glycogen is formed in the liver, whereas it is again produced soon after food is taken. Glycogen is formed in the liver from albuminous material, from fat, but principally from carbohydrates contained in the blood. Glycogen is stored as such in the liver cells, and only when carbohydrates are needed in the economy a quantity of the stored glycogen is transformed into sugar and enters as such the general circulation.

A certain quantity of carbohydrate material is constantly required by the tissues for their metabolic processes, and this quantity is conveyed to the tissues in the form of sugar in the arterial blood. Ordinarily the quantity of sugar in arterial blood is from 0.1 to 0.2 per cent; if it exceeds 0.3 per cent it is excreted as sugar with the urine, as is observed in the pathological condition known as *diabetes mellitus.* The arterial blood derives its requisite quantity of sugar from the glycogen of the liver.

When no carbohydrates are taken with the food the liver forms the necessary quantity of glycogen from the albuminous ingredients and fat in the blood.

All carbohydrates taken with the food are absorbed as sugar; they are conveyed with the blood of the portal vein into the liver, and here they are transformed into glycogen. If all sugar absorbed in the portal vein would directly enter the general circulation there would be an undue increase of sugar in the blood, resulting in the excretion of sugar with the urine.

From the foregoing explanation it may be said that the glycogenetic function of the liver has for its purpose the regulation of the quantity of sugar in the blood.

It has been found that small quantities of glycogen are also formed in muscles and other tissues; during the activity of these tissues the glycogen in them is transformed into sugar and consumed.

The *fats* which are taken with the food are absorbed into the lacteals and constitute, together with the lymph in the intestinal lymphatics, the *chyle.* In this form they are conveyed into the receptaculum chyli, and from this, by the thoracic duct, into the venous blood. In the blood the fats disappear in about thirty hours, and it is evident that they are elaborated, but exactly how and where this takes place is not known. It is believed that fat is elaborated to some extent in the lymphatic glands, and that it takes part in the assimilative processes in these organs. The mate-

rials which the tissue elements require for their assimilative processes are carried thither with the arterial blood, but the nature of the process of the assimilation of these materials into the living protoplasm of the cells has not been satisfactorily explained.

Many organs in the body, such as the thyroid and thymus glands and the suprarenal capsules, of which we know very little as regards their physiological functions, are considered as organs in which important metabolic processes take place, and the fact that the extirpation and diseases of these organs are often followed by very marked systemic disturbances tends to demonstrate their importance in the metabolism of the body.

The *thyroid* gland is a ductless gland which in structure resembles the spleen. The organ is situated in front of the upper part of the trachea; it consists of two lobes which are situated on each side of the trachea, and of a transverse portion which connects the two lobes and is called the *isthmus*. The whole organ is surrounded by a thin connective-tissue capsule, from which prolongations pass into the organ and divide it into compartments; these are filled with a brownish-red substance which is composed of a dense capillary network enclosing oval or roundish bodies or vesicles; these latter are lined with cubical or columnar epithelial cells, and are filled with a yellowish, viscid fluid in which have been observed red blood-corpuscles in various stages of disintegration. The gland contains numerous lymphatics, which surround the vesicles and capillaries. The contents of the lymphatics are similar to those of the vesicles, and are emptied into the right lymphatic duct. The thyroid gland is freely supplied with blood-vessels and nerves.

The physiological function of the organ is, as I have stated before, not clearly understood. It is believed that it partakes in the formation of blood ingredients. Extirpation of the gland is followed by tetanus, epileptic

attacks, etc. Animals in which the gland is totally extirpated generally die soon after the operation. This is believed by some to be due to injuries of important vessels and nerves, branches of which supply the organ; again it has been demonstrated that after a partial extirpation of the gland, even if only a small portion of the organ is left, no such symptoms follow. All these observations and experiments tend to show that the organ has some connection with important metabolic processes in the body.

A hypertrophy of the thyroid gland, resulting in the formation of a *goitre* or *struma*, is a pathological condition which occurs in certain mountainous districts. It is believed that the condition is caused by certain minerals which are taken in with the drinking-water. Of late the treatment of certain diseases with the extract of the thyroid gland has revealed satisfactory results.

The *thymus* gland is a temporary organ; at birth it weighs about 1½ ounces; it increases until the second year, and then diminishes, atrophies, and becomes entirely obliterated at about puberty. The gland consists of two lateral lobes, which are united in the middle. The organ is situated in the thorax and neck; in the thorax it is contained in the upper mediastinum behind the sternum and in front of the pericardium; in the neck it lies in front of the trachea, extending up to the lower border of the thyroid gland. The organ has a pinkish color and is about 2 inches long and one-half to 1 inch wide.

The structure of the thymus gland resembles that of the lymphatic glands. It has a fibrous capsule, prolongations of which penetrate the organ and constitute its cortical portion, the reticulum of which supports numerous lymphoid cells. The medullary network consists of fine branched cells with more granular, cellular, and corpuscular bodies in their centre. It has been observed that in the medullary portion of the thymus gland there are contained granular masses of hæmoglobin. The thymus gland is

ductless: it is freely supplied with blood-vessels, nerve-fibres, and lymphatics. The lymph leaving the gland has been found to contain masses of hæmoglobin.

The physiological function of the thymus gland is believed by some to be the formation of the leucocytes in embryonic life; others believe that the thymus gland is the organ in which in early life the erythrocytes, or the hæmoglobin of these, originate.

The *suprarenal capsules* are two oval, flattened, yellowish bodies contained in the abdominal cavity behind the peritoneum and situated in front of the upper part of the kidneys.

The structure of these organs is somewhat complex. They are covered with a fibrous capsule which sends columnar prolongations perpendicularly into the organ; these fibrous prolongations contain non-striated muscular fibres and communicate by transverse fibrous bands, thus forming a network which in its meshes contains masses of granular, nucleated, many-sided cells, and, between these, fine lymph-channels. The medullary portion is situated behind the cardiac portion thus described. The medullary portion consists of a delicate stroma of connective-tissue fibres, and in this stroma are cells which resemble columnar epithelial cells. The arteries supplying the organ penetrate and anastomose in its substance, and break up into a capillary plexus in the medullary portion. The organ is supplied freely with lymphatics and nerve-fibres.

The physiological function of these organs is unknown. Some believe that they play a rôle in the production of the pigments. In a disease which was first fully discussed by *Addison*, the skin shows a peculiar bronze discoloration, and it has been found in post-mortems performed on patients who died of *Addison's disease* that the suprarenal capsules had undergone degenerative changes.

The metabolic processes in the animal body depend upon a proper supply of nutritive material, upon a proper physiological activity of the tissue elements, and upon a

proper circulation. There must be a current which supplies the nutritive materials, and a current which drains off the waste products; the latter are excreted by the excretory organs.

During the period of growth, development, and the regeneration of tissues in the body the assimilative processes are most active and require an increased supply of proper nutritive material. Almost all tissues and structures of the body possess in a varying degree the power of regeneration. For instance, fractured bones, wounds and defects in tissues resulting from disease or surgical interference, are repaired owing to the regenerative processes which take place in the affected tissues. The process of regeneration of a tissue is the result of the assimilation of materials of the blood into the histological elements of that tissue.

By the term dissimilation is meant the processes which take place in the ingredients of the body resulting in the production of waste materials. The dissimilative changes are chemical processes consisting in a division, oxidation, and hydration of the chemical ingredients of the body. The final products of these changes are urea, carbon dioxide, and water, and these are excreted from the body.

QUESTIONS AND EXERCISES.

SUBJECT.—*Assimilation.*

Lecture XXVII.

553. What is the nature of the chemical changes which the nutritive materials undergo during their assimilation into tissue ingredients ?

554. Where are the ingredients of the blood formed ?

555. Where do the lymph ingredients originate ?

556. Describe the structure of the spleen.

557. Give the proportion of the white to the red blood-

corpuscles in the blood of the splenic artery and in that of the splenic vein.

558. What is meant by the glycogenetic function of the liver?

559. Explain the purpose of the glycogenetic function of the liver.

560. What materials does the liver transform into glycogen?

561. What is glycogen, its chemical formula and test?

562. What is diabetes mellitus?

563. Describe in detail how you would determine the presence of sugar in the urine.

564. Describe the thyroid gland. State where it is located. What is supposed to be its physiological function?

565. Describe the thymus gland. State where it is located. What is supposed to be its physiological function?

566. What are the suprarenal capsules? What is supposed to be their physiological function?

567. How is a regeneration of the tissues effected?

568. What are essential conditions for assimilative processes?

569. What is the nature of the chemical changes which the ingredients of the body undergo during dissimilation?

570. By what channels is the nutritive material conveyed to the tissues, and by what channels are the products of the dissimilative processes of the tissues carried off?

571. Name structures in the body whose functions are doubtful or unknown.

572. Define assimilation.

573. What are the functions of the liver?

574. In what manner are nutrition and repair carried on?

575. What effects are produced in the system by removal of the thyroid gland?

576. State the source and uses of the lymph.

577. What are the two sources of income of the body?

LECTURE XXVIII.

1. THE KIDNEYS AND THE EXCRETION OF THE URINE. 2. THE SUDORIFEROUS GLANDS AND THE EXCRETION OF SWEAT.

THE products of the retrogressive changes of the body and its ingredients are chemical substances which when retained in the organism produce serious disturbances of its functions. An important function of the animal organism is the constant elimination of these substances. They are called the *excrementitious substances;* carbon dioxide and urea are the two principal members of this group.

Carbon dioxide is produced constantly in the body as the result of the combustion of the carbon of its organic ingredients; it is eliminated principally by the process of respiration.

Urea is the final product of the oxidation of organic nitrogenous ingredients of the body. The urea, and a series of organic nitrogenous compounds which are intermediary products of the retrogressive changes of the organic nitrogenous ingredients of the body, are eliminated largely in solution. These liquids are called the *excretions.* The organs which regulate the elimination of the excrementitious substances are called the *excretory* organs. The principal excretory organs of the human body are the kidneys and the sweat-glands of the skin. The liquids excreted from these organs also contain materials which are not excrementitious substances—for instance, water, inorganic salts, etc.; these principally serve to aid the process of elimination and the solution of excrementitious substances. The liquids secreted by the excretory organs are termed the *excretions,* in contradistinction to the liquids

secreted by other organs in our body—namely, liquids which are intended to serve some function in our organism; they do not contain excrementitious substances as their principal ingredients, and they are called the *secretions*. The digestive juices, milk, seminal fluid, are secretions; the urine and the sweat are excretions. A portion of the excrementitious substances is also eliminated with the fæces.

1. *The Kidneys.*

The principal excretory organs of the human body are the kidneys. These, two in number, are situated in the posterior part of the abdominal cavity behind the peritoneum, at either side of the vertebral column, in the lumbar region. Each kidney is about 4 inches long, 2½ inches wide, and 1 to 1½ inches thick, and weighs from 4 to 6 ounces. A kidney is bean-shaped and directed with its concave part, which is termed the *hilus* of the kidney, toward the spinal column. Each kidney is surrounded and held in its place by a *fibrous capsule*, which at the hilus is reflected upon the structures which leave and enter the organ at that point; these are the renal artery and vein, lymphatics and nerves. The excretory duct of the kidney is called the *ureter*. This begins at the hilus from the opening of the pelvis of the kidney; it then descends in the abdominal cavity and opens into the bladder at its lateral and posterior side.

The *pelvis* of the kidney is a funnel-shaped excavation into the organ, which at the hilus is continuous with the ureter. The pelvis is divided into three compartments, which are termed the *infundibula*. Each of these has a number of minor sacculated recesses which are called the *calices*; into these the uriniferous tubules pour their secretion. From the calices it passes into the infundibula, filling the pelvis of the kidneys, from which the urine flows through the ureters into the bladder. The pelvis of the kidneys is lined with transitional epithelium which is continuous with that lining the bladder and ureter.

The structure of the kidneys is very complicated and requires a thorough study, as only one thoroughly familiar with the structure of these organs can understand their physiological function.

The substance of the kidneys consists of two structures —namely, the medullary and the cortical portion; the two can be plainly distinguished with the naked eye on a cross-section of a kidney.

The *medullary* portion consists of pyramidal masses of a pale-reddish color. These pyramidal masses are called the *pyramids of Malpighi.* They are directed with their bases toward the outer or cortical portion of the organ; in each of the calices of the latter is seen a minute papillary projection, which is the apex of one of these pyramids.

The *cortical* portion is darker red in color and granular in appearance ; it forms the outer convex portion of the kidney and fills the spaces left between the pyramids of Malpighi. That portion of the cortical substance which arches over the bases of the Malpighian pyramids is termed the *cortical arch.* In it are seen, radiating from the bases of the Malpighian pyramids toward the periphery, light-colored pyramidal columns, which are called the *pyramids of Ferrein.* The portions of cortical substance which are situated between the Malpighian pyramids are called the *columns of Bertin.* The structures of which the two portions of the kidneys are composed are:

1. The uriniferous tubules.
2. Blood-vessels.
3. Lymphatics and nerves.
4. Connective tissue which holds these structures together.

The *uriniferous tubules* are long tubes which penetrate the substance of the kidney ; they consist of a delicate basement membrane which is lined with epithelial cells ; these differ in their form, structure, and arrangement in the various portions of the tubules. The uriniferous

tubules begin at the cortical substance of the kidney, and, after taking a very circuitous course through it, they open into the calices of the pelvis of the organ. The peculiar appearance which the surface of a cross-section of the kidney presents—namely, the pyramids of Malpighi and Ferrein—and the granular appearance of the cortical substance, are produced by the peculiar and characteristic course of the various portions of the uriniferous tubules

In their progress through the substance of the kidney the uriniferous tubules frequently change their course. The diameter of a uriniferous tubule is not the same throughout, but varies in different portions. These variations in the course, size, and epithelial lining of the uriniferous tubules are essential features for the physiological activity of the kidneys.

A uriniferous tubule is, for the purpose of a better description, divided into several parts. I will first mention their names and respective diameters, and then describe the course of a uriniferous tubule through the kidney.

The names of the various portions of a uriniferous tubule and their respective diameters are :

		Inch.
1. The capsule of Bowman,	diameter,	$\frac{1}{125}$
2. The neck,	"	$\frac{1}{1000}$
3. The proximal convoluted tubule,	"	$\frac{1}{500}$
4. The spiral tube,	"	$\frac{1}{600}$
5. The looped tube of Henle; this consists of :		
(*a*) the descending limb,	"	$\frac{1}{2500}$
(*b*) the looped portion,	"	$\frac{1}{1000}$
(*c*) the ascending limb,	"	$\frac{1}{1000}$
6. The distal convoluted tube,	"	$\frac{1}{500}$
7. The collecting tube of Ballini,	"	$\frac{1}{625}$
8. The principal duct,	"	$\frac{1}{300}$
9. The papillary duct,	"	$\frac{1}{100}$

The course of a uriniferous tubule through the substance

of the kidney, and the epithelial lining of its various portions. are as follows: A uriniferous tubule begins as a round expansion, called the *capsule of Bowman*, in the *labyrinth*—that is, in the spaces between the pyramids of Ferrein.

The capsule of Bowman consists of a delicate basement membrane which is continuous with that of the whole tubule; the inner surface of the capsule is lined with a single layer of flat epithelial cells. The interior of Bowman's capsule is partly filled by a convolution of capillary blood-vessels called the *Malpighian tuft* or *glomerulus Malpighii*, and is covered on its surface with a single layer of flat epithelial cells which are continuous with those lining the capsule. The Malpighian tuft, together with the capsule of Bowman in which it is contained, is called a *Malpighian body*.

At the point where the capsule of Bowman joins the proximate convoluted tubule there is a constriction called the *neck*. The tube then widens again and passes in a tortuous course downward between the pyramids of Ferrein. This portion is termed the *proximal convoluted tubule;* the interior of this is lined with a single layer of columnar or polyhedral epithelial cells; the protoplasm of these is more homogeneous and cloudy in that part which is directed toward the lumen, whereas the part toward the basement membrane is more striated; the striæ diverge toward the basement membrane, giving to that part of the protoplasm a brush-like appearance; the protoplasm contains a round nucleus which is situated near the free surface of the cell; during activity the border of these cells is also striated. The next portion of the uriniferous tubule is the *spiral tube.* It is spiral-shaped, as the name implies; it is a little narrower in diameter than the previous portion, and is lined with epithelial cells similar in structure to those lining the convoluted tubule.

The uriniferous tubule now enters the Malpighian pyra-

mid, its diameter suddenly narrows, and, after a straight descent in the pyramid almost to its apex, it turns and passes straight up. This portion of the uriniferous tubule is called the *looped tube of Henle;* it consists of a *descending limb*, a *loop*, and an *ascending limb.* The *descending limb* is the portion which passes downward in the Malpighian pyramid; this portion is narrow in diameter and is lined with a single layer of flattened, elongated, and nucleated cells. The *looped portion* of Henle's tube has again a wider diameter and is lined with short columnar cells. The *ascending limb* of Henle's tube is of the same diameter as the loop and is lined with the same epithelium; in its upper portion this ascending limb has a slightly spiral course. This portion of the tube passes upward to the base of the pyramid and on to the pyramid of Ferrein, where it widens and becomes the *convoluted tube.* As the tube again re-enters the cortical portion at the base of the pyramid of Ferrein it widens and becomes convoluted, and is called the *distal convoluted tubule.* This portion is wide and has the same diameter as the proximal convoluted tubule; it is also lined with short columnar epithelium, and passes in a tortuous course through the cortical portion beneath the capsule of the kidney. The uriniferous tubule now re-enters the pyramid of Ferrein; it becomes a little narrower and passes down in the pyramid of Ferrein and in the Malpighian pyramid almost to its apex; this portion of the tube is called the *straight* or *collecting tube of Bellini;* it is also lined with columnar epithelium. Near the apex of the Malpighian pyramid a number of such collecting tubes join and form a short tube, the *principal tube*, and again several of these open into one tube, called the *papillary duct;* from 200 to 300 of these open at the surface of a papilla which is formed by the projection of the apex of a Malpighian pyramid into the calices of the infundibula.

The various names used in describing the tubular system of the kidney merely designate the various portions of one

long, continuous tubule—namely, a uriniferous tubule which passes through the substance of the kidney, often changing its course and diameter.

The epithelial cells lining the uriniferous tubule constitute the *parenchyma* of the kidney; these cells are of the short columnar variety in all portions of the uriniferous tubule, with the exception of those lining the capsule of Bowman and the descending limb of Henle's looped tube, which are of a flat variety. It is of great importance for the understanding of the physiological function of the kidney to remember the varying diameters of the several portions of the uriniferous tubules, particularly the sudden narrowing of the neck and the descending limb of Henle's tube.

The arrangement of the blood-vessels in the kidneys is also complicated and characteristic. The kidneys are supplied with blood by a branch of the abdominal aorta called the *renal artery;* this enters the kidney at the hilus and gives off branches which pass into the columns of Bertin—viz., the masses of cortical substance between the Malpighian pyramids; these branches pass up along the sides of the Malpighian pyramids and then arch over their bases; they are called the *arterial arcade.* From these, two sets of arterioles are given off—namely, the *arteriæ rectæ* and the *interlobular* arteries. The arteriæ rectæ are small arterioles which pass straight down in the Malpighian pyramids and form capillary loops which surround the uriniferous tubules. The interlobular arteries are small arterioles which pass straight upward in the pyramids of Ferrein and give off branches which pass into the cortical substance, where one such arteriole enters each capsule of Bowman and breaks up into a capillary plexus known as the *Malpighian tuft.* From this another arteriole is formed, which passes out of Bowman's capsule opposite the point where the afferent arteriole enters the capsule; the afferent arteriole, immediately after leaving the capsule, breaks up

into a secondary capillary plexus which surrounds and supplies the uriniferous tubules in the cortical portion.

The veins of the kidneys arise (*a*) from numerous small venous plexuses which are situated directly beneath the capsule of the kidney and are described as the *stars of Verhayen;* (*b*) from the capillary plexus which surrounds the uriniferous tubules in the cortical portion; and (*c*) from the capillary plexus which surrounds the uriniferous tubule in the Malpighian pyramids.

The venules arising from the stars of Verhayen, and those arising from the capillary plexuses surrounding the uriniferous tubules in the cortical portion, form the *interlobular* veins which open into the venous arcades. The venules arising from the capillary plexuses surrounding the uriniferous tubules in the pyramids of Malpighi form the *venæ rectæ*; these ascend in the pyramids, and at their bases open into the venous arcade.

The *venous arcade* surrounds the Malpighian pyramids, like the arterial arcade, and passes down between the Malpighian pyramids, forming branches which unite and form the *renal vein*, which leaves the kidneys at the hilus.

The peculiarities and characteristics of the blood circulation—particularly of the arterial—in the kidneys consist, first, in that each portion receives a separate blood-supply, as it were, by direct branches from the arterial arcade, and, secondly, in that the interlobular arterioles break up into a secondary capillary plexus after leaving Bowman's capsule. This arrangement of the circulatory system of the kidneys is an important factor in the physiological activity of these organs.

The lymphatics of the kidneys begin by minute channels in the parenchyma and from lymph-spaces beneath the capsule of the organ. The lymph-vessels pass out at the hilus and communicate with the lumbar lymphatic glands.

The nerves of the kidneys are derived from the renal

plexus, the fibres being principally distributed to the walls of the blood-vessels.

The Urine.

The excretion of the kidneys is called the *urine.* Normal human urine is generally a clear liquid which has a pale-yellowish *color;* if the urine is concentrated its color is darker, even reddish. In many pathological conditions the color of the urine is altered by the admixture of blood, pus, bile, etc. The taking of certain drugs often influences the color of the urine, as, for instance, senna produces an intense red, rhubarb a brown, and carbolic acid a black discoloration.

The *reaction* of urine is generally acid. This is not due to the presence of a free acid, but to the presence of sodium sulphate. The acidity of urine is increased by the taking of acids, and it is decreased by the taking of alkalies; also during the process of digestion, and in pathological conditions when the urine becomes mixed with pus, as it is in the case of pyelitis, cystitis, etc.

The *specific gravity* of urine is subject to variations; it is generally between 1010 and 1020; it depends upon the quantity of dissolved solids. Normally it is increased, therefore, after the taking of heavy meals, and when the urine is concentrated, as it is when long retained in the bladder owing to the reabsorption of water by the epithelial lining of the bladder. The specific gravity is decreased after drinking large quantities of water. The specific gravity is influenced by many pathological conditions: it is increased in fevers, diabetes mellitus, etc., and decreased in the condition known as polyuria.

Normal human urine has a characteristic peculiar aromatic *odor,* which is also often altered in pathological conditions and when certain drugs have been taken.

The *chemical composition* of normal human urine is as follows:

It contains about 96 per cent of water and 4 per cent of solids ; the latter are contained in the urine principally in solution, and are (*a*) organic and (*b*) inorganic substances.

(*a*) The organic ingredients are :

Urea.
Uric acid and hippuric acid.
Oxalic acid.
Oxaluric acid.
Kreatinin.
Xanthin.
Sarkin.
Coloring substances.
Indican.
Phenol.
Ferments.
Mucus.

(*b*) The inorganic ingredients are : Sodium and potassium chloride, sodium sulphate, and phosphates and sulphates of lime and magnesia.

Urea is the final product of the oxidation of the nitrogenous substances in the body. The chemical formula of urea is $CO(NH_2)_2$; it is an organic nitrogenous substance composed of $CO_2 + (NH_4)_2 - H_2O$. It crystallizes in colorless, glistening, quadrangular prisms and in needles ; the crystals are neutral in reaction, taste bitter, and are freely soluble in water and in alcohol, but insoluble in ether.

Normal human urine contains from 2½ to 3 per cent of urea. A healthy adult man excretes about 30 to 40 grammes of urea with the urine in twenty-four hours; this quantity is increased when food rich in nitrogenous substances is taken, and is decreased when a small amount or no albuminous material is taken with the food. The quantity of urea in the urine varies at different periods of the day, and is influenced by many other conditions. It is increased by muscular exercise, decreased by rest and fasting; it is highest several hours after a meal.

Increased dissimilative changes in nitrogenous tissue ingredients increase the quantity of urea in the urine; such is the case in febrile conditions and in chronic wasting diseases.

Urea is also found in small quantities in the blood, lymph, chyle, bile, in the liver, spleen, brain, lymphatic glands, etc.

The liver is believed to be the organ in which the urea is formed; experiments made on animals tend to sustain this theory.

The two sources of the urea in the animal body are: 1. The organic nitrogenous food ingredients. 2. The degenerative processes of the nitrogenous tissue ingredients.

Uric acid is also an organic nitrogenous substance; its chemical formula is $C_5H_4N_4O_3$; it crystallizes in rhombic plates, is odorless, colorless, and tasteless, and but slightly soluble in water. In the human urine it is generally found in the form of urates of sodium and potassium, which are soluble in water. The quantity of uric acid excreted in twenty-four hours is about 0.5 to 2 grammes. The source of uric acid is probably the same as that of urea, as it is proportionally increased and decreased with this. It has been observed that the quantity of uric acid is increased in pathological conditions where there is a disintegration of the leucocytes.

The other *organic nitrogenous ingredients* mentioned are all products of the retrogressive changes of nitrogenous substances in the body; they are all present, but in small quantities, and often only accidental ingredients. *Hippuric acid* is the chief product of the retrograde changes of the nitrogenous ingredients in the herbivora; in human urine it is also found, but only in small quantities.

The *coloring substances* of human urine are *urobilin* and *urochrome;* they are organic nitrogenous substances derived from the bile-pigments.

Indican and *phenol* are two substances which are products formed during the pancreatic digestion of nitrogenous food.

It has been demonstrated that urine contains *ferments* which have a slight diastatic and peptic action; the exact nature of these ferments is not understood. Urine often contains traces of *sugar*, especially so after the taking of foods or drinks containing sugar.

The small quantity of *mucus* which urine contains is secreted by the cells and glandular organs contained in the mucous membrane of the urinary tract.

The *inorganic* solid ingredients of the urine are principally the salts which are taken in with the food; the principal one is *sodium chloride*.

The *phosphates* and *sulphates* are to some extent also formed during the decomposition of the organic nitrogenous substances of the body.

The *carbonates* are largely formed from the CO_2 which is the product of the oxidation of the carbon of the organic ingredients and materials in the body. Urine contains a considerable quantity of free CO_2.

The urine of the herbivora contains more carbonates in proportion than sulphates and phosphates, and is therefore generally alkaline; this abundance of carbonates is due to the union of CO_2 with the potassium salts of the herbs and fruits.

The *water* of the urine is the excess contained in the tissues and in the blood. Such excess interferes with the metabolic processes of the organism and is therefore eliminated; this is clearly shown by the increase of water in the urine following the drinking of large quantities of liquids.

The quantity and quality of the ingredients are determined by chemical tests. You will learn this in your practical course in urinalysis.

LECTURE XXIX.

THE EXCRETION OF URINE.

The physiological process of the excretion of the urine, and the mechanism connected with it, have been the subject of much study and discussion, and many valuable observations and experiments in this direction have been made by men such as *Bowman*, *Ludwig*, *Heidenhain*, *Nussbaum*, and many others, and various theories as to the exact details have been advanced. The results of the many observations and experiments on the subject may be summed up as follows :

1. The urine is formed in the kidneys, but the larger portion of the principal excrementitious substances contained in it are not formed in the kidneys ; they are formed in the tissues and organs of the body, are taken up by the blood, and excreted from it by the kidneys.

2. A small quantity of the ingredients of the urine is formed in the kidneys as the product of chemical processes in them ; this applies, for instance, to some of the salts which cause the acidity of the urine.

3. The processes which effect the excretion of the urine are : (*a*) filtration, (*b*) osmosis, (*c*) the vital property of the epithelial cells lining the uriniferous tubules.

4. The water of the urine, and some of its more easily diffusible ingredients, such as salts, are excreted from the blood in the capillary plexus—viz., the glomerulus in the Malpighian bodies—by a process of filtration caused by the pressure of the blood in this plexus.

5. The solid ingredients of the urine are, to the greatest extent, excreted in the convoluted portions of the urinifer-

ous tubules from the blood in the capillary plexus surrounding it.

The principal ingredients of the urine are not formed in the kidneys, but in the tissues and organs of the body, from which they are taken up by the blood. This is shown by facts. Most of the ingredients of the urine—for instance, urea—are found in the blood as such in small quantities; these rapidly increase and accumulate, producing convulsions, coma, and death whenever their elimination is interfered with, as, for instance, in certain pathological structural changes in the kidneys. The same result is obtained when the renal arteries are tied or when the kidneys are extirpated.

The excretion of the water of the urine is believed to take place principally in the Malpighian bodies of the uriniferous tubules by a process of filtration.* The Malpighian body has the essential structure of a filter. The glomerulus or primary capillary plexus of the renal artery is the membrane through which the filtration takes place. The blood in this capillary plexus is the fluid to be filtered; to effect this it must be subjected to a certain pressure. The blood-pressure in this capillary plexus is greater than in other capillaries, because the afferent vessel which conveys the blood into the plexus is greater than the efferent vessel which carries the blood off from the plexus, and, furthermore, because the current of blood from this plexus meets a further resistance in the secondary capillary plexus of the renal artery—namely, the plexus which surrounds the tubular portions of the uriniferous tubule. The cavity into which the fluid is filtered is the space between the outer surface of the glomerulus and the inner surface of the capsule of Bowman; this cavity is lined by a single layer of flat epithelial cells. By this process of filtration not only water, but also some of the more easily diffusible ingredients of the urine—for instance, salts—are excreted from the blood. This excretion, however, cannot be con-

sidered as produced alone by filtration, as such a process would also cause certain substances of the blood which normally are not found in the urine to pass through the capillary walls. The small degree of diffusibility of many of the blood ingredients—for instance, albumin—cannot be considered as the reason for their not filtering through the walls of the capillaries of the glomerulus together with the water and other substances, because, in the pathological structural conditions in which the epithelial lining of the Malpighian bodies is destroyed, albumin and other substances which normally are not found in the urine are filtered through the walls of the capillaries into the uriniferous tubules, even if the blood-pressure in the renal artery is not increased. It is believed that the special vital property of the epithelial cells lining the uriniferous tubule consists in their possessing a special affinity for certain ingredients of the blood—namely, the normal ingredients of the urine; they thus favor the excretion of these substances and to some extent prevent the excretion of others. This special vital property of the epithelial cells must therefore be considered as an important factor in the mechanism of the excretion of urine. It has been demonstrated by experiments that the largest portion of the solid ingredients of the urine is excreted by the epithelial cells lining the convoluted portions of the uriniferous tubules, from the blood in the capillary plexus surrounding them. The process of excretion in this part of the tubule is not effected by a filtration, but by the physiological activity of the epithelial lining, and it is believed that the excretion of substances in this part of the uriniferous tubule is to some extent effected by osmosis. That the solid ingredients of the urine are principally excreted in this part of the uriniferous tubule is proved by the following experiment: If a solution of sodium sulpho-indigotate is injected into the blood the eliminated urine will soon show a deep-blue discoloration; this is due to the fact that the particles of the

sodium sulpho-indigotate are excreted by the kidneys. If during this process a kidney is extirpated and examined it will be found that the structures which are formed by the convoluted tubules are stained blue, whereas the other parts are not stained at all. If examined microscopically it will be found that this is due to the presence of the particles of the staining materials in the protoplasm of the epithelial cells lining the convoluted tubules, whereas the cells lining the other portions of the uriniferous tubules do not contain any such particles. The peculiar structure of the epithelial cells lining the convoluted tubules, and the change observed in these cells during their activity, also tend to sustain the theory that they excrete the solid ingredients of the urine.

That the excretion of substances in this part of the uriniferous tubules is not produced by a filtration is evident, because the pressure of the blood in the capillary plexus surrounding this portion of the tubes is not greater than in any other capillaries. The pressure is not sufficient to cause a filtration, because the urine in the convoluted tubule has a tension sufficient to prevent a filtration of substances from the blood through the capillaries into the convoluted tube. The tension of the urine in the convoluted tube is maintained by the small calibre of the straight portions of the uriniferous tubules, which permits only a slow and gradual flow of the urine in the convoluted tubule.

The normal urine contains a greater proportion of urea and other solid ingredients than the blood.

Taking into consideration the fact that in the Malpighian bodies only a comparatively small quantity is filtered through the glomerulus together with the water, it follows that urine passing from Bowman's capsule into the convoluted tubule is a very dilute solution of solids in water. In the convoluted tubule the urine becomes more concentrated, owing to the admixture with the particles of solid ingre-

dients excreted by the epithelial cells. The exact nature of the excretion of the substances by these cells is not fully understood, but it is likely that they possess a special affinity for the substances which are formed as ingredients of normal urine. It is believed that there takes place an osmotic current between substances in the blood of the capillary plexus surrounding the convoluted tubules and substances of the urine in the convoluted tubules, and that during this osmotic current certain ingredients of the blood having comparatively high endosmotic equivalents are exchanged for a quantity of water of the urine in the convoluted tubule. This osmotic current is aided by the slow flow of the urine from the convoluted tubules through the narrow, straight portions of the uriniferous tubules. This also explains the greater degree of concentration of the urine in the convoluted tubule as compared with that formed in Bowman's capsule. The passing of the solid matter through the epithelial cells lining the convoluted tubules is believed to be produced in a manner similar to the passing of the particles of fat into the lacteals through the epithelial cells covering the villi—namely, by motions of the protoplasm of these cells.

The Quantity of Urine Excreted; Conditions Influencing It.

The quantity of urine excreted in twenty-four hours by the healthy adult is subject to very great variations; 1,500 cubic centimetres is about the average.

The excretion of urine is *increased:*

1. By all conditions which increase the general blood-pressure; for instance, increased cardiac action, contraction of blood-vessels (general or local), obstructions to venous flow, etc.

2. By drinking large quantities of liquids, and the consequent tendency of the system to eliminate the superfluous water, which retards the metabolic processes.

3. By a contraction of the blood-vessels of the skin,

which retards the elimination of water from the surface of the body, as is the case in cold weather.

4. By taking foods rich in nitrogenous materials.

5. By the use of *diuretics* These are drugs which, by their effect on the circulatory system, increase the excretion of urine.

The excretion of urine is *decreased:*

1. By all conditions which decrease the general blood-pressure.

2. By large hemorrhages, sweats, and diarrhœas.

3. By fasting and when small quantities of liquids are taken.

4. When foods containing small quantities of nitrogenous materials are taken.

5. In warm weather, when the vessels of the skin are dilated, thus favoring the elimination of water from the skin.

The quantity of urine depends upon the quantity of water excreted by the kidneys, and is therefore influenced principally by the blood-pressure, and consequently by all the conditions which influence the blood-pressure. The quantity of solids in the urine depends upon the taking of such foods as produce their formation, upon the metabolism of the tissues, and upon the excretory activity of the epithelial cells lining the uriniferous tubules. The presence of abnormal ingredients in the urine is often due to pathological lesions, as, for instance, the presence of sugar in diabetes mellitus, or the increase of phosphates in nervous diseases, etc. Sometimes an increase in the blood-pressure is the cause of the presence of abnormal ingredients in the urine, as, for instance, the presence of albumin in cardiac diseases; and, lastly, structural changes in the kidneys must be mentioned as a frequent cause of the presence of abnormal ingredients in the urine.

The quantity of urine excreted at the various periods of the day also varies. At night it is at its minimum; it

increases in the forenoon, reaches its maximum two to three hours after the main meal, and gradually decreases again toward night. The quantity is influenced by the quantity of liquids and kinds of food taken, by the temperature and physical activity during the various periods of the day. The excretory activity of the kidneys is continuous. The activity of both kidneys is not equal at all times. It has been observed that when one kidney is extirpated the other will assume the excretory activity for both.

The Nerve Influence on the Excretory Function of the Kidneys.

The excretory function of the kidneys is principally influenced and regulated by the vasomotor nerve-fibres, which arise from a special nerve-centre located in the floor of the fourth ventricle of the brain.

The fibres arising from this centre pass down in the spinal cord to the renal plexus and are distributed from it to the kidneys, terminating in the walls of the blood-vessels. Injury to the vasomotor centre of the vascular system of the kidneys causes a dilatation of the blood-vessels of the same and a consequently increased excretion; section of the renal plexus has the same effect.

Paralysis of the vasomotor nerves of a large portion of the body causes a decrease in the excretion of urine. This results from a decreased blood pressure in the renal vessels, caused by a dilatation of the walls of the blood-vessels, the vasomotor nerves of which have been paralyzed. The presence of special secretory nerve-fibres in the kidneys has not been demonstrated.

The Evacuation of Urine.

The urine, which is constantly secreted by the kidneys, passes through the ureters into the urinary bladder. The *ureters* are the excretory ducts of the kidneys.

The ureter begins as a funnel-shaped expansion at the

hilus of the kidney; it gradually becomes a cylindrical tube of the size of a goose-quill, which passes obliquely downward and inward through the abdominal cavity into the pelvis, where it opens into the bladder at its base.

A ureter consists of a fibrous, a muscular, and a mucous coat; the latter is lined by transitional epithelium. The muscular coat consists of circular and muscular fibres.

The *urinary bladder* is a musculo membranous sac; it is located in the pelvic cavity behind the pubes and in front of the rectum. The bladder serves as a reservoir for the urine; it is about five inches long and three inches wide, and holds about one pint.

The bladder consists of an upper portion, the *apex*, a middle portion, the *body*, and a lower portion, the *base* or *fundus*. The organ is suspended by a fibrous band, the *urachus*, which passes from the apex of the bladder to the umbilicus. The posterior surface of the bladder is covered with peritoneum; the anterior and lateral sides have no serous covering. The anterior part of the base of the bladder is at one point somewhat constricted; this is called the neck, and is the commencement of the urethra. The bladder is composed of four coats—namely, serous, muscular, submucous, and mucous.

The *serous* coat is derived from the peritoneum; it covers the bladder only posteriorly.

The *muscular* coat consists of three layers of non-striated muscular fibres—namely, an *outer longitudinal*, a *middle circular*, and an *internal longitudinal layer*. The circular fibres form around the neck of the bladder a thick muscular ring—the *sphincter vesicæ*.

The *submucous* coat consists of areolar tissue and serves to support vessels, etc.

The *mucous* coat is lined with transitional epithelium.

The bladder is supplied with blood-vessels and nerves; the latter are derived from the pelvic plexus, which is

formed by fibres from the sympathetic and from the third, fourth, and fifth sacral nerves.

The factors of the passing of the urine from the kidneys through the ureters into the bladder are: 1. The force of the urine constantly formed in the kidneys. 2. The peristaltic contractions of the muscular fibres of the ureters. 3. When the body is in an erect position, the gravity of the urine.

The urine is eliminated from the bladder through the *urethra.* This is a membranous canal which is lined with mucous membrane continuous with that lining the whole genito-urinary tract.

The urethra extends from the neck of the bladder to the *meatus urinarius*, which is the outer opening of the urethra. In the male the urethra pierces the penis; in the female it passes through the anterior wall of the vagina beneath the symphysis pubis.

The Act of Micturition.

The act of the evacuation of the urine which has collected in the bladder is called *micturition.* This is a nervous reflex act, which to some extent is under the control of the will.

The nerves which regulate the mechanism of the act of micturition are:

1. A special nerve-centre which is located in the lumbar region of the spinal cord.
2. The motor nerve-fibres to the involuntary muscular fibres of the walls of the bladder. These nerve-fibres pass from the spinal cord to the anterior roots of the third and fourth sacral nerves.
3. The motor nerve-fibres to the sphincter urethræ. These also pass from the cord with the anterior roots of the third and fourth sacral nerves.
4. Nerve-fibres conducting a voluntary motor impulse to the motor fibres of the sphincter urethræ pass from the

cerebrum through the spinal cord to the motor fibres of the sphincter urethræ ; the exact course of these fibres in the cord is not known.

5. Inhibitory nerve-fibres, which conduct inhibitory impulses for the reflex contraction of the sphincter urethræ, pass from the brain to the centre of micturition.

6. The sensory fibres of the bladder and of the urethra pass to the cord in the posterior roots of the third, fourth, and fifth sacral nerves, and pass up to the brain, conveying stimuli which produce the sensation of a filled bladder and the desire to micturate.

The mechanism of the reflex act of micturition is as follows : The pressure of the urine filling the bladder is a stimulus which is conveyed by the sensory fibres of the bladder to the brain, producing the sensation of a filled bladder, and at the same time producing reflex contraction of the involuntary muscular fibres of the walls of the bladder. The increased pressure of the contracting walls of the bladder upon the urine forces the latter against the inner opening of the urethra ; the irritation thus produced causes a reflex contraction of the sphincter urethræ. The continual increase of the pressure upon the urine forces drops of the same into the urethra ; this irritation conveys a stimulus to the brain through the sensory nerves of the urethra ; the result is that an impulse inhibiting the reflex contraction of the sphincter urethræ passes from the brain, through the inhibitory fibres, to the centre of micturition.

Voluntary micturition is effected by a voluntary relaxation of the sphincter urethræ and a contraction of the abdominal muscles exerting a pressure upon the bladder, forcing its contents into the urethra.

Section, injury, or disease of the spinal cord above the third sacral nerves causes *retention* of urine, because the fibres are severed which conduct inhibitory impulses for the reflex contraction of the sphincter urethræ. This muscle is therefore in a constant state of contraction, and urine

is only eliminated by drops when the force exerted upon the urine filling and extending the bladder becomes so strong that drops of urine are forced into the urethra. Section of the cord above the exit of the third sacral nerve also makes voluntary micturition impossible.

Section of the anterior roots of the third and fourth sacral nerves, which contain the motor fibres for the sphincter urethræ, produces *incontinence* of urine. This is also produced by section of the posterior roots of these nerves, for they contain the sensory fibres which convey to the centre the stimulus for the reflex contraction of the sphincter urethræ. Certain psychical events, such as fear, fright, shock, etc., often cause an involuntary reflex micturition. In infants the reflex contraction of the sphincter urethræ is not so strong as in the adult, hence the involuntary micturition of infants whenever the bladder becomes filled.

2. *The Sweat-Glands and their Excretion. The Structure of the Sweat-Glands.*

The sweat-glands of the skin are tubular glands which begin as a coil in the subcutaneous tissue of the skin; their duct is spiral, pierces the corium and epidermis, and opens upon the free surface.

The glands consist of a delicate fibrous membrane, the interior of which is lined by a single layer of epithelial nucleated cells, which in the smaller sweat glands have a flattened cubical, and in the larger glands a columnar, form. The basement membrane of the larger sweat glands also contains plain muscular fibres. The total number of sweat-glands in the human adult is from 2,000,000 to 2,500,000; they are most abundant in the palms of the hands, the soles of the feet, in the axillæ, and in the groins.

The secretion of the sweat or *sudoriferous* glands is an excretion, because it contains excrementitious substances, although only in minute quantities.

Sweat is a clear, colorless liquid which has a saline taste and generally an acid reaction. Its chemical composition is as follows:

Water, 995 parts.
Solids, 5 "

The *solids* are:

Organic acids.
Fat.
Cholesterin.
Urea and other extractives, about 1:1000.
Epithelial cells.
Inorganic salts.

The excretion of sweat is regulated by nerve influence. It has been demonstrated that in the brain and spinal cord there are located special sweat-centres. It is very likely that the activity of the sweat-glands is due to special secretory fibres; to a great extent, however, the activity of these glands is influenced by vasomotor nerves. The drugs which increase the excretion of the sweat—namely, the *diaphoretics, i.e.*, pilocarpine—and the drugs which decrease the excretion of the sweat, as, for instance, atropine, act by their influence on the vasomotor nervous system.

The expression "sensible perspiration" is used when the sweat collects in drops upon the skin, whereas the expression "insensible perspiration" is used when the sweat evaporates from the skin as soon as it is excreted. The quantity of water which is thus eliminated from the body in twenty-four hours by a healthy adult under ordinary circumstances is about 2 to 2½ pounds.

QUESTIONS AND EXERCISES.

SUBJECT.—*The Excretions.*
Lectures XXVIII–XXIX.

578. Name the principal excrementitious substances formed in the animal body.

579. Name the principal excretory organs of the human body.

580. Distinguish between excretion and secretion.

581. Describe the microscopical appearance of a human kidney.

582. Name the various portions of a uriniferous tubule, and give their respective diameters.

583. Describe the course of a uriniferous tubule through the substance of the kidney.

584. Describe the epithelial lining of the various portions of a uriniferous tubule.

585. Describe the course of the renal artery through the kidney, and point out any peculiarities in the vascular system of a kidney.

586. Trace the renal vein through the kidney.

587. Describe a Malpighian body.

588. What is the color, reaction, and specific gravity of normal human urine?

589. What are the coloring substances of the urine?

590. Upon what does the reaction of the urine depend?

591. Give the variations within the limit of health in the specific gravity of urine.

592. Give the chemical composition of normal human urine.

593. Describe urea, its occurrence, variations in the quantity excreted, and recognition in the voided urine.

594. What is the quantity of urea excreted by a healthy adult with the urine in twenty-four hours?

595. Where is the urea formed in the animal body?

596. What is the mechanism of urinary excretion?

597. Discuss the nerve influence on the excretory function of the kidneys.

598. Describe the structure of the ureters.

599. Describe the structure of the urinary bladder.

600. Describe the mechanism of micturition.

601. Give the nervous mechanism of the act of micturition.

602. What is the average quantity of urine voided in twenty-four hours by a healthy human adult?

603. Mention the conditions (*a*) which increase, (*b*) those which decrease this quantity.

604. Describe the sudoriferous glands.

605. What is the composition of sweat?

606. Through what organs is the expenditure of waste of the body?

607. Where is the urine formed, and where its ingredients?

608. Describe the physiological action of the kidneys.

609. What changes take place in the blood as it passes through the kidneys?

610. What relation does the nervous system bear to the excretion of perspiration?

611. What is the function of the sudoriferous glands?

612. Name the excretory glands of the body and the function of each.

613. Explain three ways by which waste matter is excreted from the system.

614. Name the solids of the urine, and state the approximate amount of each voided daily by an adult.

615. Name and describe an excreting gland.

LECTURE XXX.

THE SECRETIONS.

THE *secretions* are fluids which are secreted from the blood and are intended to serve or aid physiological processes.

The secretions of the human organism are:

1. The digestive juices.
2. The secretion of the mucous, serous, and synovial membranes.
3. The milk.
4. The secretion of the seminal glands.
5. The secretion of the lachrymal glands.
6. The secretions of the sebaceous, Meibomian, and ceruminous glands of the skin.

Most of these secretions I have already described, together with their uses and physiological function.

Milk is the secretion of the mammary glands. These are two lobulated glands situated beneath the skin in the mammary region of the chest of the female. The gland consists of *lobes*, which again are made up of *lobules*, the *ductules*, and larger ducts of these unite to form the *lactiferous* ducts, 15 to 20 in number, which terminate in minute openings in the *nipple*.

The structures composing the gland are held together by areolar and by adipose tissue; the external surface of the gland is covered with skin. The secreting portions of the lobules are lined with polyhedral cells. The period when the glands secrete is termed the *period of lactation*. This begins at the end of pregnancy, shortly before which the gland undergoes an *evolution*; it becomes larger,

harder, the nipple becomes more prominent, and the pigmentation of the skin surrounding the nipple becomes darker. At the same time changes take place in the epithelial cells lining the acini of the gland. At the termination of the period of lactation the gland undergoes changes which result in its return to the normal condition; these changes are known as the *involution* of the gland.

The formation of milk in the glands during the period of lactation is produced by a fatty metamorphosis of the epithelial lining of the glands.

The *human milk* is an emulsion of minute fat globules in a solution of water, casein, serum-albumin, milk-sugar, and inorganic salts; it has an alkaline reaction and a specific gravity of 1030.

The exact composition of human milk and its value as an infant food I have already described in a former lecture. The use and function of human milk is to nourish the new-born infant: it is, therefore, a true secretion.

The secretion of the *seminal* glands serves reproductive functions. I will describe these, therefore, in connection with that subject.

The secretion of the *lachrymal* glands serves to moisten the conjunctivæ.

The secretions of the *sebaceous*, *Meibomian*, and the *ceruminous* glands of the skin serve to keep the skin pliable, to prevent an undue escape of water from the surface, and to protect it from the macerating effect of water.

The secretions of these glands must, therefore, be described as a secretion; they are, however, considered by some as excretions, because, as a rule, they contain small amounts of excrementitious substances.

The apparatus for the process of secretion consists essentially of the following structures: 1. Epithelial cells. 2. A basement membrane supporting these. 3. Blood-vessels. 4. Nerves.

The secretory organs are: 1. The membranes. 2. The glands.

1. The *membranes* are the serous, synovial, and mucous. They consist of a basement membrane and, superimposed upon this, one or more layers of epithelial cells. The secretions of the membranes—viz., that of the serous membranes, the *serous fluid;* that of the synovial membranes, the *synovia;* and that of the mucous membranes, the *mucus*—serve to moisten and lubricate these surfaces.

2. The *secreting glands* also consist of a basement membrane, an epithelial lining, and a blood and nerve supply.

According to variations in their form and minute structure, the secreting glands are divided into: 1. *Simple tubular*, consisting of a simple tubular depression or involution. The mucous follicles in the mouth, the crypts of Lieberkühn, are glands of this type.

2. *Compound tubular:* In these the tubules divide and subdivide. The glands of the stomach may be classed in this variety.

3. *Racemose* or *acinous* glands, in which the secreting portion consists of a roundish expansion or lobules, giving to the gland the appearance of a bunch of grapes. The salivary glands, the pancreas, and the sebaceous glands of the skin are of this variety. The racemose glands are by some authorities further subdivided into *simple* and *compound* racemose glands.

The process of secretion is effected by physical and chemical processes.

The *physical* processes are (*a*) filtration and (*b*) diffusion.

The *chemical* processes consist in the formation of certain ingredients of the secretion which do not pre-exist as such in the blood, but are the product of chemical processes taking place in the cells.

The process of secretion of an organ may be *continuous* or it may be *interrupted.* The process is influenced by: 1. The blood supply to the gland. 2. The nerve supply.

The character of a secretion depends to a certain extent upon a physiological property of the epithelium of the secreting organ. This special property of these cells consists in a special affinity for certain materials of the blood, and in a peculiar elaboration of certain materials within these cells.

THE SKIN AND ITS FUNCTIONS.

The Structure of the Skin.

The *skin* is a membrane which covers the exterior of the body. It is from 2 to 3 millimetres thick and rests upon a subcutaneous cellular tissue. The latter is composed of an areolar network and contains more or less adipose tissue ; it serves to support the blood-vessels, nerves, and other structures of the skin.

The *skin proper* consists of the *corium* or *cutis*, and the *epidermis* or *cuticle.*

The *corium*, or *cutis vera*, rests upon the subcutaneous and adipose tissue. It is composed of a reticulum of elastic and white fibres, which consists of many layers ; these, passing in all directions, form a dense and elastic structure. In the deeper layers the meshes of the reticulum are larger and contain fat ; the upper layers are very dense and interwoven with plain muscular fibres. From the surface of the cutis vera are projected numerous cone-like elevations called the *papillæ ;* they have either a single or branched free extremity. These papillæ are most important, for they are organs of the special sense of touch; they contain capillary blood-vessels and the terminals of sensory nerves—viz., the *tactile corpuscles.*

The papillæ are most abundant in the skin of the palms of the hands and the soles of the feet, and it is for this reason that in these parts the sense of touch is more acute than in other portions of the body. I will describe the tactile corpuscles with the subject of the special sense of touch.

The *epidermis*, or *cuticle*, consists of numerous layers of cells which are superimposed upon the cutis vera, and which are held together by an intercellular cementing substance. The cells of the epidermis are arranged in four distinct strata, each consisting of cells of varying shapes. These four strata are :

1. The *stratum corneum*, which consists of numerous layers of squamous, horny cells. The varying thickness of these layers produces the variations in the thickness of the skin in the different parts of the body, as the other structures of the skin have a more or less uniform thickness.

2. The *stratum lucidum* is situated beneath the former. It consists of layers of flattened cells which have a clear, homogeneous protoplasm, and sometimes have nuclei.

3. The *stratum granulosum* consists of a layer of flattened cells which have a granular protoplasm and a distinct nucleus.

4. The *stratum Malpighii*, or *rete mucosum*, consists of many layers of various shaped cells. The deepest layer consists of cells which are nucleated and have a columnar form. These cells cover in a uniform layer the cutis vera and its papillæ. The layers external to this layer of columnar cells consist of many-sided cubical cells. The middle layers of the rete Malpighii consist of branched cells which are connected by their processes and are called *prickle cells*. The outer layers of the rete Malpighii consist of more flattened cells.

The deeper layers of the stratum or rete Malpighii contain the pigment to which the coloration of the skin is due.

The epidermis serves to protect the cutis vera. The touching of clothes, friction, handling, and other mechanical injuries to which the surface of the body is subjected, cause a constant wearing-off of the outer layers of the stratum corneum of the epidermis. This is replaced by cells from the deeper layers, so that the epidermis constantly maintains its thickness. This new formation of

cells in the deeper layers of the epidermis takes place in such a manner that the columnar cells of the rete Malpighii divide into a lower portion which retains the columnar shape, and an upper portion which assumes the more polyhedral form of the cells of the middle layers of the epidermis. By the constant repetition of this process the new-formed cells are pushed toward the outer layers of the epidermis, and in the stratum corneum they become more and more flattened and scaly.

The Glands of the Skin.

The skin is provided with two sets of glands—namely, the sudoriferous or sweat-glands and the sebaceous glands.

The sudoriferous glands and their secretion, the sweat, I have already described in my last lecture when speaking of the excretory organs and of the excretions.

The *sebaceous glands* are small, compound racemose glands; they are most abundant in the parts of the body which are supplied with hair; they are absent in the skin of the palmar surface of the hand and plantar surface of the foot.

The sebaceous glands consist of a lobulated, secreting portion which is lined with polyhedral, flattened, nucleated cells, and a duct which opens either direct upon the skin or into a hair-follicle at its side. The interior of these glands is filled with a whitish, soft, fatty matter called the *sebum*, formed as the product of the proliferation, fatty degeneration, and final breaking-down of the cells lining the glands.

The chemical composition of the sebum is as follows: fats, as olein and palmitin; cholesterin; albuminous matter; extractives; organic acids—butyric, caproic, etc.; aromatics; inorganic salts, principally insoluble phosphates.

Examined under the microscope the sebum contains fat granules, cholesterin crystals, epithelial cells, and a peculiar micro-organism, the *demodex folliculorum*.

The sebum is an oily liquid; sometimes it becomes semi-solid in the gland, forming the so-called *comedones.*

The secretion of the sebaceous glands serves to keep the skin and hair soft and pliable, to prevent an undue escape of moisture, and to protect the skin from the effects of long-continued exposure to moisture.

The *Meibomian* glands of the eyelids, and the *ceruminous* glands of the skin covering the interior of the external ear, are tubular glands resembling in their structure the sudoriferous glands; their secretion, however, in its composition resembles to a greater extent the sebum and serves the same purpose.

The Hair.

The skin is covered in almost all locations with *hair;* in some parts it is thick and strong, in others very thin and delicate and called *lanugo.* A hair is the result of a peculiar development of the epidermis. It consists of an external layer of flat, scaly cells which are arranged like tiles, with the free edge upward; this layer is called the *cuticle* of the hair. Beneath this there is a layer of thick, elongated horny cells. In the centre of a hair there is sometimes a space which is filled with smaller cells, pigment granules, and fat; this is called the *medulla* of the hair.

The lower portion, or *root,* of each hair is contained in a tubular depression from the skin; this is called the *hair-follicle.* It descends into the subcutaneous cellular and adipose tissue, where it terminates in a bulbous expansion. The follicle consists of a delicate basement membrane which is surrounded by blood-vessels; its interior is lined with squamous cells continuous with those covering the exterior of the epidermis. From the fundus of the hair-follicles a *papilla* projects into the cavity of the same; this papilla is composed of the structures of the cutis and is covered on its surface by epidermal cells. The hair is

formed by a peculiar development and growing upward of the epidermal cells covering the hair-papilla.

Into the hair-follicle at its side opens generally one, sometimes two, sebaceous glands.

From the fibrous membrane to the upper layer of the cutis there passes a layer of plain muscular fibres; a contraction of these causes the standing-up of the hair, and, by the pressure upon the sebaceous glands, forces their contents into the hair-follicle.

The hair-follicles are supplied with nerve-fibrilli which terminate in the plain muscular fibres of the follicle. These nerve-fibres arise in the spinal cord and are contained in the sympathetic nerve-trunks; stimulation of these causes the standing-up of the hair in the localities to which they are distributed.

Hair begins to develop in the twelfth or thirteenth week. During the nineteenth to twenty-fifth week the hair begins to cover the skin of the fœtus.

The color of the hair is due to the development of pigment in the medulla. The gray color of hair in advanced age is due to insufficient development of pigment and to the presence of air-bubbles in the medulla. These, owing to their refractive power, give to the gray hair the silvery, glistening appearance. The sudden gray discoloration of hair produced by psychical events, such as fright, fear, etc., is believed to be due to the production of such air-bubbles in the medulla.

The Nails.

The *nails*, like the hair, are produced by a peculiar development of the epidermis. A nail projects from a convex groove in the skin of the dorsum of the digit. It projects beyond the end of the digit, and rests with its lower surface upon the dorsal surface of the end of the digit. The convex groove in the skin of the dorsum of the digit in which the root of the nail is lodged is termed

the *matrix* of the nail. The flat surface of the digit, upon which the nail rests with its under-surface, is called the *bed* of the nail. The matrix is formed by a peculiar arrangement of the cutis vera. It is covered with elevated ridges, and from the epidermal cells covering them the nail develops as a result of the constant multiplication and pushing forward of these cells. The nail consists of various layers of epidermal cells, the outer ones being very horny.

The Functions of the Skin.

The skin possesses several important functions. These may be enumerated as follows:

1. The skin is an excretory organ. I have already spoken of this function in my last lecture when speaking of the sudoriferous glands and their secretion, the sweat. The importance of the skin as an excretory organ is best shown in pathological disturbances of the excretory functions of the kidneys, in which the skin often tends to aid in the elimination of excrementitious substances from the body. For instance, in *urœmia* the percentage of urea in the sweat is greatly increased. The secretions of the other glands of the skin must also, to a certain extent, be considered as excretions. It has been observed that when the excretory function of the skin has been interfered with, compensation for this is made by the kidneys.

2. The skin prevents an undue escape of heat from the surface of the body, because the subcutaneous cellular and adipose tissue, the cutis vera, and the epidermis are bad conductors of heat.

3. The skin protects the surface of the body. (*a*) The delicate anatomical structures on the surface of the body are protected by the soft subcutaneous tissue and by the elastic, tough, leathery skin covering it. (*b*) The absorption of poisonous substances is prevented by the thick layers of the epidermis and by the fatty secretion of the

sebaceous glands. Skin does not absorb substances from a watery solution, but does so from solutions which dissolve the sebaceous secretions—viz., alcohol, ether, and chloroform. The epidermis, and the fatty sebaceous matter permeating it, protect the cutis and underlying parts from the macerating effect of a long-continued exposure to moisture.

4. The skin is an organ of respiration. In connection with the subject of respiration I have already spoken of the respiratory activity of the skin.

5. The soft adipose and subcutaneous cellular tissue and the elastic skin serve to protect underlying delicate structures, to fill out depressions and irregularities, and to cover rough surfaces, thus giving to the surface of the body a round and plastic form.

6. The skin is an organ of touch. This function the skin possesses owing to the nerve terminations—viz., the tactile corpuscles in the papillæ of the cutis vera.

From this description and enumeration of the functions and uses of the skin the importance of this structure will be clearly understood. It has been demonstrated that animals whose skin has been varnished soon die.

Loss of a large surface of skin by burns or other injuries is often followed by serious disturbances, and necessitates replacement of skin by plastic operations or skin-grafting.

QUESTIONS AND EXERCISES.

SUBJECT.—*The Secretions. The Skin and its Functions. Lecture XXX.*

616. What do you understand by secretion?

617. Name the secretions of the body and give the functions of each.

618. Describe the mammary glands.

619. Give the composition and uses of human milk.

620. Describe the structure of the skin.
621. Name the glands of the skin.
622. What are the functions of the skin?
623. Describe the sebaceous glands.
624. What are the composition and function of the secretion of the sebaceous glands?
625. What are (*a*) the Meibomian glands? (*b*) the ceruminous glands?
626. What is the function of the sudoriferous glands?
627. Describe the structure of a hair.
628. Describe the structure of a nail.
629. Name and describe the various layers of epidermis.
630. Name the essential structures of a secreting apparatus.
631. Name the secretory organs of the human body.
632. Name the membranes and their secretions.
633. Name and describe the varieties of secreting glands. Give examples of each.
634. Name the conditions influencing secretion.
635. By what processes is secretion effected?
636. Upon what does the nature of a secretion depend?
637. How is secretion produced when food enters the mouth?
638. Define secretion.

LECTURE XXXI.

THE FORCES OF THE ANIMAL ORGANISM.

1. Animal Heat. 2. Animal Motions.

THE metabolism of the animal organism results in a production of living forces.

Living or *kinetic* force is the force which manifests itself as heat, light, electricity, and mechanical work. The imperceptible force which exists in all matter is termed *potential force.*

The physical laws relating to the forces in nature assert that there is no spontaneous generation or destruction of force, but that a new form of force results from a change of some other form.

In the animal organism the potential forces which are stored in the nutritive materials taken are transformed into living forces. In the human organism two forms of living force are observed—namely, animal heat and animal motions.

Formerly the manifestations of animal heat and animal motions, and physiological processes such as growth, development, and metabolism of the tissues, were considered as manifestations of a force peculiar to living organisms, which was called the *vital force.* At the present time this is not considered a satisfactory explanation by most scientists, but it is believed that also these more complicated physiological phenomena are the result of physical and chemical processes of a complicated nature not fully understood.

1. Animal Heat.

The heat which is constantly generated in the animal

body is called animal heat, which must be considered as a rapid vibration of the atoms composing the matter of the animal body, caused by the constant molecular changes taking place in the body ingredients. The potential force contained in these may be considered as latent heat which is transformed into a living force—namely, measurable heat.

The science which treats of the temperature of bodies is called *thermometry*. The instruments used to determine the degree of heat of bodies are the *thermometer* and the *thermo-electrical apparatus*.

It has been observed that many animals maintain a body temperature independent of any thermal changes in the surrounding atmosphere; such animals are called *homoiothermal* animals. Their body temperature is generally higher than that of the surrounding atmosphere; they are consequently warm to the touch, and are called *warm-blooded animals*. Other animals, again, change their temperature with that of the medium in which they live; they are called *poikilothermal* animals; they are generally cold to the touch, and are called *cold-blooded animals*. The mammalia, birds, and man are homoiothermal; the fishes and reptiles are poikilothermal animals.

The average temperature of the human body in health is 98.6° F. = 37° C.

The temperature of the human body varies in different parts. As a rule it may be said that it is lower in the parts most exposed, which are least active, and in which the least chemical processes take place; and that, on the other hand, it is highest in the parts least exposed, which are most active, and in which the greatest chemical changes take place, as in the internal organs, muscles, and glands. Thermometrical observations have shown that venous blood is a little warmer than arterial; that the blood in the right side of the heart is a little warmer than that of the left side; and that the blood in the hepatic veins and in the liver is

almost 1° C. warmer than that in the aorta. Furthermore, it has been observed that the temperature of the muscles, organs, and glands is higher during their activity than during rest. All these variations are but slight, and it may be stated that the temperature in the various parts of the human body varies from 98.6° F. to 100.4° F. = 37° to 38° C.

The instrument most used by the clinician to ascertain the body temperature of individuals is the clinical thermometer.

Sanctorius, in 1626, made the first thermometrical observations on the human body. To-day the clinical thermometer is the principal instrument in the armamentarium of the physician. In this country thermometers with the Fahrenheit scale are employed, while in European countries the Celsius, or centigrade, scale is generally used.

To obtain the body temperature the thermometer is placed in the mouth under the tongue, in the vagina, or in the rectum; the latter location is preferable.

Careful observations have demonstrated the fact that the temperature of the human body in health shows diurnal variations. During the day it continually rises, reaching its maximum between 6 and 8 P.M., and during the night the temperature continually decreases, reaching its minimum at 3 to 6 A.M. The temperature is increased by muscular exercise and after taking food; it is decreased by fasting and rest. Climatic conditions to some extent influence the body temperature; it is slightly increased during the summer and decreased in cold weather. Sex and race apparently do not influence the body temperature.

In children and infants the temperature is generally lower than in middle-aged persons; in old age it is again lower. All conditions which influence the metabolism of the tissues—pathological conditions, many drugs, surgical operations, etc.—often influence the body temperature, and it is for this reason that the clinician should be perfectly familiar with the subject of thermometry.

The principal source of animal heat is the oxidation or combustion of the nutritive materials in the body.

The oxygen required for the combustion is taken through the lungs. The main quantity of the animal heat is produced by the combustion of the carbon of the organic nutritive materials with the production of carbon dioxide. About 25 per cent of the animal heat is produced by the combustion or oxidation of the hydrogen of the nutritive materials with the production of water. A small quantity of heat is produced in the body by other chemical processes; friction, motion, etc., also tend to produce heat.

We may therefore enumerate the sources of animal heat as follows:

1. The combustion of carbon.
2. The combustion of hydrogen.
3. Other chemical processes.
4. Physical processes, such as friction, motion, electrical currents in muscles, glands, etc.

It may be said, however, that when the body is at rest the entire potential force contained in the nutritive materials is transformed into heat. The products resulting from the combustion of the nutritive materials of the body contain a much smaller quantity of potential force than the nutritive materials. The production of animal heat consists, therefore, in a transformation of materials with a high potential force into substances with a low potential force.

The quantity of heat which is produced by the oxidation or combustion of the various substances can be measured, and is expressed by *heat-units* or *gramme-calories*.

One *heat-unit* or one *gramme-calorie* is the quantity of heat required to raise the temperature of one cubic centimetre of water one degree centigrade.

The science which treats of the study and methods of ascertaining the quantity of heat contained in a body, or the quantity of heat which is produced by its combustion, is termed *calorimetry*.

The apparatus generally used for these experiments is the *water-calorimeter.*

A *water-calorimeter* consists of a cylindrical box, the *combustion chamber*, which receives the materials to be burned. This is suspended in a vessel which contains a stated quantity of water of a stated temperature. This vessel is surrounded by a thick layer of material which is a poor conductor of heat, and is again suspended in another vessel with water. The non-conducting surrounding of the walls of the inner cylinder, and the water in the outer cylinder, serve to prevent an escape of heat. The water in the inner cylinder, in which the combustion-chamber is suspended, is heated by the heat produced by the burning of materials in the combustion-chamber. The quantity and temperature of the water in this inner cylinder are ascertained and noted before the beginning of the process of combustion; during this the increase of the temperature of the water in the inner cylinder is noted by means of a thermometer. The upper portion of the whole apparatus is closed by covers made of non-conducting materials. Through these covers four tubes pass into the combustion-chamber. One tube is provided with a glass plate and a mirror; this permits an observation of the process in the combustion-chamber.

The second tube passes nearly to the floor of the combustion-chamber; this serves to admit the air required for the combustion. A third tube leading into the combustion-chamber serves to introduce gases when the heat produced by their combustion is to be ascertained. This tube is closed by a stop-cock.

The fourth tube consists of a lead coil which passes through the water surrounding the combustion-chamber; it opens into this at its upper portion. This tube serves to give exit to the gases formed in the combustion-chamber during combustion; these gases, while passing through the many coils of the leaden tube, cool by transmitting

their heat to the metallic walls of the tube, which again transmit it to the water through which the tube winds. Knowing the exact quantity of water contained in the inner cylinder, and its exact temperature before the process of combustion begins, and knowing the quantity of material burned in the combustion-chamber, it remains only to ascertain the temperature of the water contained in the inner cylinder after the complete combustion of the substance in the combustion-chamber, and it is then easy to calculate the number of heat-units of the substance burned in the combustion-chamber.

Favre, *Silverman*, and others have determined by calorimetric experiments the quantity of heat produced by the complete oxidation of carbon, hydrogen, and of the principal nutritive materials. The results of these experiments, expressed in heat-units, are as follows :

Carbon,	8,100.
Hydrogen,	3,450.
Albumen,	4,998.
Fat,	9,069.
Carbohydrates,	9,745.

The combustion of these substances in the calorimeter is much more rapid than in the animal body, but it is otherwise the same process.

Fats and carbohydrates are completely oxidized in the body. Albuminous substances are not completely oxidized; about one-third of their weight is excreted as urea, which has 2,206 heat-units. One-third of this must therefore be subtracted from the heat produced by the complete oxidation of albumen, so that the heat produced by the combustion of one gramme of albumen in the human body equals only 4,263 heat-units.

Knowing the quantity of heat-units produced by the combustion of one gramme of each of the food or nutritive materials, it is easy to determine the total quantity of heat-units produced in the body by determining the number of

grammes of each of the nutritive materials taken with the food. From this it has been estimated that in the body of a healthy man taking a mixed diet of 125 grammes of albumen, 80 grammes of fat, and 300 grammes of carbohydrates, about 3,000,000 heat-units are produced. This number, however, is not exact, as a portion of the food materials is always unabsorbed, and it has been calculated that the loss of heat thus caused is about 8 per cent of the total amount, which, subtracted from the amount given, leaves about 2,800,000 as the total number of heat-units produced in the human body under the conditions mentioned.

This quantity of heat which is produced in the body by the combustion of materials constitutes about 75 per cent of the total amount of heat generated in the body. The remaining 25 per cent is produced by other chemical processes and by physical action.

The temperature of the animal body is regulated:

1. By a constant elimination of heat from the body.
2. By the constant heat production in the body.

Both the production and elimination of heat are influenced by various conditions, such as the quantity and quality of food taken, the external temperature, nerve influence, muscular action, the blood-supply, etc. Experiments which have been made to ascertain the comparative amount of heat which is given off from the body in various ways have given the following results.

Of the total quantity of heat produced in the body, 80.5 per cent is given off from the skin by radiation and evaporation; 14.5 per cent is given off by evaporation from the lungs; 2.5 per cent is given off with the expired air; 2.5 is given off with the urine and fæces.

The production of heat within the body, and the elimination of heat from the body, regulate themselves in such a manner as to keep the temperature of the body at a certain degree.

During cold weather the vessels of the surfaces of the body contract, decreasing the blood-supply to these, and thus decreasing the giving-off of heat from the surfaces of the body. During warm weather the reverse condition takes place: the vessels dilate, more blood is supplied, and consequently more heat is given off; the increased blood-supply also causes an increased excretion of sweat, with which a quantity of heat is eliminated. The same conditions take place when the heat production is increased by great muscular activity.

The heat production within the body is to a certain extent self-regulating. In cold weather the process of combustion is more active than in summer. This is shown by the fact that in cold weather the consumption of oxygen and the production of carbon dioxide are greater than in summer. Another factor in the regulation of heat production is muscular activity; this is more active in cold than in warm weather.

It has been shown that heat regulation in the body is also influenced by nerves. Section of larger nerves is followed by an increased temperature in the parts supplied by the nerve. Section of the spinal cord is followed by an increased temperature in the parts below the point of section. Injury to the brain in the vicinity of the pons Varolii and medulla oblongata is also followed by a rise in the body temperature. These observations tend to show that the body temperature is influenced by nerves, and it was formerly believed that there were special caloric nerves and centres; later observations, however, have shown that these thermal changes are caused by a dilatation of the blood-vessels resulting from section or injury or irritation of vasomotor nerves and centres.

An increased normal body temperature is termed *fever* This is a constant symptom of many pathological conditions, and is caused either by the increase of the heat production in the body, a decrease of the heat elimination

from the body, an increase of the metabolism of the tissues, or a disturbance of the regulation of the body temperature. Fever is generally accompanied by a rapid pulse, rapid respiration, and dry and red skin. A temperature of 100° to 102° F. indicates a mild fever; a higher temperature shows severe fever. High fever often causes death by its interference with many of the important physiological processes of the body. Long-continued febrile conditions are often followed by fatty degeneration of muscular tissues.

The body temperature can be artificially raised and lowered. Cold baths decrease the temperature, and are often used for this purpose in the treatment of fevers.

Exposure of the body to air having a very low temperature interferes with the heat regulation of the body.

Persons overcome by exposure to cold air are often found to have a subnormal temperature; a recovery in these cases is rare. Exposure of the body to hot air interferes with the heat elimination from the body, and an increase of the body temperature is the result.

LECTURE XXXII.

ANIMAL MOTIONS.

1. *Muscular Motion.* 2. *Ciliary Motion.* 3. *Protoplasmic Motion.*

I. Muscular Motion.

The muscles are the active organs which effect the motions of the body and its organs.

A muscle is composed of bundles of muscular fibres which are held together by connective tissue. Muscles are supplied with blood-vessels and with motor and sensory nerves.

In the higher developed animals we find two varieties of muscular fibres—viz., the striated and the non-striated. The minute structure of these I have already described in my preliminary lectures on histology.

The special function and physiological property of muscles is, first, their power of moving their substance, producing a forcible shortening of the muscle. This property is known as *contractility*, and the exhibition of this property is known as a muscular contraction.

The contraction of certain muscles in the body is controlled by the will of the individual. These are called the voluntary muscles, whereas those muscles which cannot be contracted by an effort of the will are called the involuntary muscles. A muscle in an animal body may be in a state of *rest* or in a state of *activity.* After death the muscle passes into a state known as *rigor.*

The muscle changes its physical, chemical, and electrical conditions as it passes from one state into another.

These changes are due to the metabolic processes taking place in the muscle; the effect of these metabolic processes is heat and labor. The changes taking place in the muscle after death, as it passes into the state of rigor, must be considered as the result of retrogressive processes.

To understand the changes which take place in muscle as it passes from one state into the other, it is best to consider the conditions of the muscles in these states.

The Condition of Muscles in a State of Rest.

(*a*) *Physical.*—The muscles in the animal body are attached with their free ends to some other anatomical structure. Muscles are slightly elastic, and they are always somewhat stretched beyond their natural length between their points of attachment, so that a muscle has always a certain tension. This condition has for its purpose the saving of labor. If the muscle when in a state of rest should be in a relaxed condition, then a certain amount of muscular force would be lost in making the muscle tense between its points of attachment. That such tension exists in the resting muscle is best shown by the fact that a muscle, when cut, at once shortens until it has assumed its natural length.

(*b*) *Chemical.*—The reaction of living muscle in a state of rest is neutral or slightly alkaline.

The chemical composition of living muscle cannot be determined accurately, as any chemical treatment which may be employed for an analysis causes death of the muscle.

Muscle is composed of 75 to 80 per cent of water and 20 to 25 per cent of solids; the largest portion of the latter consists of albuminous substances.

The principal albuminous ingredient of muscle is *myosin.* It is believed to be an ingredient of living muscle, because it is obtained by a process which causes the least chemical change—namely, by freezing and a subsequent simple manipulation.

If a living muscle—for instance, that of the frog—be frozen, then divided minutely and the mass then squeezed through a cloth, a turbid, yellowish liquid is obtained, called the *muscle-plasma*. It is alkaline, and coagulates at ordinary temperature into a clot and a clear, yellowish liquid, the *muscle-serum*.

The *clot* is composed of the myosin, which has separated from the plasma in whitish flakes.

The *muscle-serum* is acid, is composed of water, inorganic salts, principally potassium phosphate, and of organic ingredients such as serum-albumin, fat, organic acids, glycogen, dextrose, inosit, extractive substances, hæmoglobin, and CO_2.

Myosin is also obtained by treating fresh muscle with a 10 per cent solution of sodium chloride.

Myosin is an organic, nitrogenous, albuminous substance. It is soluble in dilute saline and acidulous solutions, and readily coagulable by heat and alcohol; with dilute hydrochloric acid it forms acid-albumin, known as *syntonin*.

An analysis of fresh muscle shows it to consist of (1) water, 75 to 80 per cent; (2) myosin, serum-albumin; (3) organic nitrogenous extractive substances, such as creatin, creatinin, xanthin, hypoxanthin, urea; (4) carbohydrate substances—glycogen, dextrose, inosit; (5) organic acids, principally sarcolactic acid; (6) inorganic substances—namely, potassium phosphate, calcium and magnesium phosphate, chlorides, and traces of iron; (7) gases—viz., CO_2, N, and oxygen.

(*c*) *Electrical*.—It has been observed that in animal tissues there exist natural electrical currents. It has been demonstrated that these exist in muscle.

To *E. Du Bois-Reymond* must be given the credit of having studied and explained the subject of the natural electrical currents in the animal tissues, and the laws governing them, most precisely and minutely. In his many interesting publications on electro-physiology he describes the various observations and experiments he made in this direction.

Time is too limited to dwell on the subject more than is absolutely necessary.

For his experiments *Reymond* used a pair of unpolarized electrodes, which he connected with a galvanometer.

To study the electrical currents in muscle, prismatic pieces are cut out of the living tissue. Such a prism is isolated by placing it on a glass plate, and the electrodes are applied to its various points; the currents are indicated on the galvanometer. Such a muscle prism has a longitudinal and a transverse section. The longitudinal section runs parallel with the long axis of the muscle fibres; the transverse section is the transversely cut portion. A line passing transversely across the middle of the longitudinal section is termed the *equator*. If now one of the electrodes is applied to a point on this equator, and the other electrode to any point distant from it, it will be noticed that an electric current passes from the electrode on the equator, through the conducting wire, to the electrode placed at the distant point, and from this point through the muscle mass to the point at or near the equator.

The point at or nearest the equator is the positive pole; the point distant from the equator is the negative pole.

The laws governing the electrical currents in muscle, as laid down by *Du Bois-Reymond*, are as follows:

1. Currents are obtained between two points on the longitudinal section of the prism, provided the points are not equally distant from the equator.

2. The points nearest the equator are the positive, those distant from the equator are the negative, poles.

3. The greater the distance between the two points the stronger the current.

4. Currents between points on the longitudinal section and points on the transverse section are the strongest.

5. Currents between two points on the longitudinal section, or between two points on the transverse section, are weak.

6. Currents between two points on the transverse section pass from the electrode most distant from the middle of the transverse section through the wire to the point nearest the middle of the transverse section; the latter point is the negative, the former point the positive, pole.

7. No currents are obtained between two points which are equally distant from the middle point of the longitudinal or from that of the transverse section.

8. The strength of the current decreases as the points between which it passes are brought nearer to the middle point, or equator, of the longitudinal section.

2. *The Condition of Muscles in a State of Activity.*

(*a*) *Physical.*—The muscle changes its form during contraction; the muscular fibres and the whole muscle become shorter and thickened without changing their volume.

(*b*) *Chemical.*—The activity of the muscle is the result of chemical processes taking place in it; during these the potential force contained in the ingredients of the muscles is transformed into living force—viz., heat and labor.

The chemical processes taking place in muscle during its activity are the dividing and oxidizing of its organic ingredients with the production of carbon dioxide, water, and sarcolactic acid.

To determine the chemical changes taking place in muscle during activity, it is necessary, first, to produce tetanic contractions, and, secondly, to cut off the blood-supply, because the blood constantly supplies new materials and carries off the products of the chemical processes.

The chemical composition and condition of fresh tetanized muscle, as compared with that of muscle in a resting state, is as follows:

1. It is acid in reaction, due to the increased quantity of sarcolactic acid.

2. It contains a smaller quantity of non-nitrogenized ingredients, such as glycogen, sugar, fat.

3. It contains more water.

4. It contains more CO_2.

5. The quantity of nitrogenous ingredients and of extractives is not materially decreased or increased.

From this description it follows:

1. That CO_2, water, and sarcolactic acid are the products of chemical changes in muscle during activity.

2. That glycogen, sugar, and fat—viz., non-nitrogenized ingredients of the muscle—are the principal sources of these products. The quantity of non-nitrogenous ingredients in muscle is not sufficient to produce the quantity of CO_2, etc., formed in muscle during activity, but it must be considered that muscle continually receives a supply of non-nitrogenous material with the blood; it has also been observed that the quantity of glycogen is greatly diminished when the muscles of the body are tetanized.

3. That the organic nitrogenous ingredients of muscle probably do not enter to any extent in the production of CO_2, water, and sarcolactic acid. Muscle in a state of rest contains a smaller quantity of organic nitrogenous extractives, and it is believed that the organic nitrogenous ingredients of muscle merely partake in the chemical processes in the muscle, in that they give off some oxygen which is taken up by the non-nitrogenous materials.

(*c*) *Electrical.*—The electrical condition of muscle also changes as the muscle passes into the state of activity. The changes taking place have been studied and observed most accurately by *E. Du Bois-Reymond.* He describes them as follows:

1. The direction of the current is changed.

2. The current is weakened, due to the greater resistance which is presented to the current by the shortening and thickening of the muscle mass.

During the activity of muscle there take place certain *thermal processes.* It is well known that muscular activity increases the body temperature, and *v. Helmholtz* has

demonstrated that during the activity of a muscle heat is produced as the result of chemical processes.

Heidenhain has ascertained, with the use of very sensitive thermal apparatus, that the temperature in the muscle of a frog is raised $\frac{5}{1000}$ of one degree C. during one single contraction.

A peculiar phenomenon observed during muscular contraction is the *muscular sound.* This is a deep, dull sound, and is easily heard by placing a stethoscope over the muscle during its contraction. The sound consists of from 16 to 20 vibrations, which shows that a muscular contraction is not continuous but interrupted. A muscular contraction is therefore not produced by one but by a succession of nerve stimuli. The changes which a muscle undergoes in its chemical, thermal, and electrical conditions, as it passes from a resting into an active state, are practically the same in the striated and in the non-striated muscles.

LECTURE XXXIII.

THE ACTIVITY OF MUSCLE.

THE activity of a muscle consists in its contraction.

A muscle passes from the resting into the active state when it receives a stimulus. The property of a muscle to respond to stimuli is termed *muscular irritability*. Ordinarily a muscle in the body receives the stimulus for its contraction through its motor nerve; this is called the *natural stimulus*. The muscles are supplied with motor nerves. The fibrillæ enter the muscular fibres and cells and terminate in a flat, granular expansion known as the *motorial end plate*, from which filaments from the axis cylinder radiate through the mass of the muscle fibre. The sarcolemma of the striated muscular fibres becomes continuous with the neurilemma of the nerve-fibre entering it. The nerve distribution to the plain or non-striated muscular fibres is more complicated.

The activity of a muscle can also be excited by chemical, mechanical, thermal, or electrical stimuli. They are called *artificial stimuli*, and they may be applied directly to the muscle or to its motor nerve.

Chemical stimuli are those which act by their chemical properties to produce certain chemical changes in muscle. Such substances are solutions of certain salts, alkalies or acids, alcohol, ether, and certain gases. If, for instance, the motor nerve of a muscle is dipped into a solution of sodium chloride, or of alkalies or acids of certain strengths, a muscular contraction is produced. The same effect is produced when the isolated muscle itself is subjected to the influence of these solutions.

Mechanical stimuli are those produced by a blow, pres-

sure, puncture, or squeezing of the muscle or its nerve. They produce their effect by causing certain molecular changes in the substance of the nerve or muscle.

Thermal stimuli are produced by the application of heat and cold. It has been observed that the application of heat or cold produces muscular contractions.

The irritability of muscle is destroyed by the application of heat or cold beyond certain limits.

Electrical stimuli. Muscular contractions can be produced by the application of electrical currents. Both the continuous and the induced current may be used to study the effect of electrical currents.

If a *continuous* current of an equal strength is passed through a muscle or applied to its motor nerve, *no* contraction is produced. This effect is only produced when the strength of the current is repeatedly and suddenly changed, and at the moments when the current is opened and closed.

An *induced* current is produced by means of an induction coil, by which the current may be interrupted at regular intervals. If such a current is applied a muscular contraction will be produced at each interruption of the current. For the purpose of studying the irritability of muscles or nerves, electrical stimuli are preferable, because they pro duce the least changes in the substance of these organs when applied in moderate strength, and also because they are easily applied and can be accurately regulated.

The contractility and irritability of muscle is an inherent physiological and characteristic property of muscle and is *not* dependent on nerve influence. This has been demonstrated by experiments made with *curare*, the Indian arrow poison. This is the juice or resin of a tree of the strychnos family. If a very small quantity of the poison is introduced into the blood circulation it produces a paralysis of the voluntary muscles and brings about death by the paralyzation of the respiratory muscles. Introduced into the stomach it produces no poisonous effect.

Curare does not paralyze the sensory and secretory nerves, nor the motor nerves of the organic muscles—viz., the non-striated and cardiac muscle. Curare only paralyzes the motorial end plates of the skeletal or striated voluntary muscles. Poisoning with curare therefore makes the individual unable to contract the skeletal muscles; the so paralyzed muscles do, however, respond to stimuli applied directly to them. This demonstrates that these muscles possess the inherent property of responding to stimuli. This property, however, ceases when the muscle is paralyzed and inactive for a long time, and the muscles in the body degenerate when severed from their nerve connection. Experiments in this direction have not been made with the organic muscles, as no mode is known by which their motor nerves can be paralyzed; but it is supposed that they also possess the inherent property of responding to stimuli independent of their nerve connection. The two varieties of muscles—viz., the skeletal or striated and the organic or non-striated muscles—differ somewhat in their mode of responding to stimuli. *Non striated* muscles respond more slowly to stimuli. When a stimulus is applied to a *non-striated* muscle a contraction of the muscle begins at the point to which the stimulus is applied, and the contraction gradually extends beyond while the portion first contracted relaxes. The effect of this is the peculiar peristaltic contraction of the organic muscles. The contraction of an involuntary muscle continues for some time after the stimulus is withdrawn. *Striated* muscles respond quickly to stimuli. When a stimulus is applied to a striated muscle an instantaneous contraction takes place in that part of the muscle to which the stimulus is applied; the contraction ceases instantaneously when the stimulus is withdrawn.

Application of a succession of electrical stimuli to a non-striated muscle by means of an induced current produces, if any, a slow contraction which alternates with periods of rest. The application of an induced current to a striated

muscle produces a tetanic contraction. Non-striated muscles respond more forcibly when a continuous current is applied. This is characteristic of the non-striated muscles in the case of thermal stimuli: application of cold produces their contraction, warmth their relaxation.

The fibres of the *cardiac* muscle resemble the non-striated fibres in their mode of contraction and in their mode of responding to stimuli.

The rapidity of the contraction also varies in the two kinds of muscles. When a muscle is stimulated the stimulus is conducted from particle to particle in the muscle; the result is that the contraction propagates from the point to which the stimulus is applied to its various particles, producing a contraction which passes with a wave-like motion over the whole organ.

In the *striated skeletal muscles* the wave of the contraction has a rapidity of from 10 to 15 metres per second; in the *organic*—viz., the non-striated and the cardiac muscle—this is much slower, namely, from 10 to 15 millimetres per second.

The Muscular Work.—The work which a muscle can do is the result of its physiological activity. When a muscle contracts it shortens and thickens. The height which a muscle assumes by its thickening is proportional to its shortening. If a muscle is loaded with a weight it will raise that weight to a certain height by the force of its contraction. The amount of work which is done by a muscle is estimated by multiplying the weight with which the muscle is loaded by the height to which it is raised in the muscular contraction. The amount of work done by a muscle is expressed in gramme-millimetres.

If A expresses the work done by the muscle, P the weight with which the muscle is loaded, and B the height to which that weight is raised, then the calculation is as follows : A = P multiplied by B. Thus, if a muscle raises a weight of 5 grammes to a height of 27.6 millimetres,

then the work done by that muscle equals 138 gramme-millimetres.

The height to which a muscle rises by thickening is greatest when a maximal stimulus is applied and when the muscle is not loaded by a weight.

The results of many observations and experiments made to explain the laws regulating the muscular work are principally the following:

1. When a muscle is not loaded with any weight as it contracts, then the work done by the same equals 0.

2. When the weight with which the muscle is loaded is so great that the muscle cannot contract—viz., that it cannot shorten and thicken, and consequently cannot raise the weight—then the muscle does no work.

3. The work done by a muscle increases and decreases as the stimulus is decreased or increased, within certain limits.

4. The height to which a muscle raises a weight with which it is loaded *decreases* as the weight *increases*.

5. The greater the physiological transverse section of a muscle, the greater the weight it can raise.

6. The longer a muscle the greater the height to which it can raise a weight.

7. The elasticity of a muscle must be considered an important factor of the muscular work.

8. The *absolute work* or power of a muscle is that done by a muscle when a maximum stimulus is applied, and when it is loaded with as much weight as it can raise without stretching.

9. A muscle becomes stronger by repeated and moderate work.

10. A muscle becomes fatigued, and finally exhausted, when overtaxed either by long-continued or too great work.

Muscular fatigue is a condition indicated by a gradual decrease of the work the muscle is capable of doing.

It is believed that the condition is due to the accumulation of the products of the metabolic processes in the muscle. Muscle recovers from its fatigued condition when these products are removed; ordinarily this is effected by the circulation.

III. The Conditions of the Muscle in a State of Rigor.

The rigor of the muscle is a condition which is caused whenever the nutrition of the muscle and its metabolic processes are interfered with.

In the condition of rigor the muscle has lost all its physiological properties and is characterized by changes in its physical, chemical, and other conditions.

(*a*) *Changes in the Physical Condition.*—The muscle loses its fresh red color and becomes whitish and opaque; it becomes stiff and firm and loses its elasticity.

(*b*) *Changes in the Chemical Condition.*—The reaction is acid, due to the increased amount of sarcolactic acid. There is a coagulation of albuminous ingredients of the muscle plasma, by which the peculiar stiffening is produced.

(*c*) *Changes in the Electrical Condition.*—There exist no natural electrical currents in a muscle in a state of rigor.

Muscular rigor is characterized by a peculiar contraction of the muscles. This produces the condition known as *rigor mortis*, which is observed in bodies after death. It begins from two to seven hours after death, and continues for two or three days. During that time the contraction of the muscles produces the peculiar stiffening and consequent inability to bend the joints in the dead during that period. Rigor mortis subsides after two or three days, owing to the beginning of the decomposition of the muscle substance.

The Function of the Involuntary Muscles.

The involuntary muscles generally have no bony at-

tachment, but they form the walls of certain hollow organs, as the heart, intestines, bladder, uterus, etc.

The function of the involuntary muscles is to produce the diminution of the hollow organs. The peculiar mode of activity and contraction is due to the more or less complicated nerve termination and distribution in muscles.

The Function of the Voluntary Muscles.

The voluntary muscles are principally the skeletal muscles. They are attached to the bones in such a manner that in the simplest form the muscle passes from one bone to another, and thus effects by its contractions the motions of the joints between the bones. The motions of the joints are effected in a manner similar to the actions of a lever; the *axis of motion* or *fulcrum* is the joint, the *power* removing the weight is the muscular action, and the *weight* to be removed is the resistance offered to the bone to be moved in the joint. There exist three varieties of levers; all three are represented in the human body. The difference between the various levers is made according to the difference in the relative positions of the power, fulcrum, and weight.

The skeletal muscles are therefore the active organs for the motions and locomotions of the body.

Standing, walking, running, leaping, and jumping are all acts for the performance of which nearly every voluntary muscle is brought into play to a greater or less degree.

II. Ciliary Motion.

Ciliary motion is the peculiar motion possessed by the minute hair-like protoplasmic processes of the ciliated cells. Such cells are found covering the mucous membrane of the respiratory passages, of the Eustachian tube, the Fallopian tubes, and the vasa efferentia. The motion of the cilia in these regions is from within outward, and has for its object the preventing of the entrance, and favoring the exit, of substances from these localities. For instance, the ciliary

motion of the epithelial cells covering the respiratory tract has for its object the removal of mucus and inhaled particles of foreign matter, such as dust, germs, etc. The ciliated epithelium covering the lining of the Fallopian tubes, by the motion of its cilia, aids the passage of the matured ovum into the uterus.

The motion of the cilia of the cells covering a surface is rapid and wavy and in a certain direction.

The motion of the cilia of a cell is not dependent upon nerve influence. If a cell is removed from the body the motion of its cilia can be observed for some time. It is very likely that the motion of the cilia is caused by stimuli from the cell-body.

Electrical currents, weak alkaline solutions, and a moderate rise of temperature favor ciliary motion; cold, great heat, solutions of acids, and CO_2 destroy the same.

The motions of the delicate filaments of the body of the spermatozoon must also be regarded as a motion similar to the motion of the cilia.

III. Protoplasmic Motion.

The best example of protoplasmic motion is the amœboid motion of the leucocytes, by which they migrate in the system, and by which they take up into their body particles of substances.

The *Brownian* movement of particles in the protoplasm of cells is probably caused by a molecular motion of the protoplasm.

QUESTIONS AND EXERCISES.

Subject.—*Animal Heat and Animal Motions. The Physiology of Muscle.*

Lectures XXXI.–XXXIII. inclusive.

Animal Heat.

639. What is meant by kinetic force—potential force—latent heat?

640. Define animal heat.

641. What is meant by homoiothermal animals?

642. What is meant by poikilothermal animals?

643. What is the average normal temperature of the healthy adult?

644. Give the sources of animal heat.

645. How is the quantity of heat ascertained which is produced by the combustion of substances?

646. What is meant by one heat-unit?

647. Describe the water calorimeter.

648. What is the total quantity of heat-units produced in twenty-four hours in the body of a healthy adult who takes a normal mixed diet?

649. How is heat eliminated from the body?

650. Give the percentage of heat eliminated in various ways.

651. How is the body temperature regulated?

652. What is meant by fever?

653. Who invented the thermometer?

654. Name the difference in the various scales of the thermometers, and give the normal temperature of the human body on the various scales.

655. Explain the method of converting the various scales one into the other.

656. What is the preferable way of taking the body temperature, and why?

657. Name diseases in which a subnormal temperature may be found.

658. How does the temperature compare with the number of pulsations and with the number of respirations?

659. What is the temperature curve in remittent, and what is it in intermittent fever, and name a type of each.

660. What is the quantity of heat-units produced by the combustion of one gramme of each of the following: carbon, hydrogen, albumen, fat, carbohydrates?

661. Is the combustion of albumens in the animal body

complete? If not, what is the ultimate product of their combustion?

662. What is the quantity of heat-units produced by the combustion of one gramme of urea?

Animal Motions.

663. Name the varieties of animal motions.

664. What is the physiological property of muscle?

665. Name the states in which muscle may exist.

666. Name the chemical and physical and electrical conditions of muscles in a state of rest.

667. Name the changes in the physical, chemical, and electrical condition in a muscle as it passes from a resting into the active state.

668. What do you understand by the muscular sound? Explain.

669. What do you understand by muscular irritability? How may it be excited, and what is the natural stimulus?

670. What do you understand by muscular work, muscular fatigue? Give cause of the latter condition.

671. What do you understand by muscular rigor?

672. What changes take place in muscle in that condition?

673. What is the function of (*a*) the voluntary, and of (*b*) the involuntary muscles?

674. What is the effect of the introduction of curare into the blood circulation?

675. Define clonic and tonic contraction.

676. What is tetanus? Trismus? Epilepsy?

677. What do you understand by ciliary motion?

678. Give example of protoplasmic motion.

LECTURE XXXIV.

THE PHYSIOLOGY OF THE NERVOUS SYSTEM.

I. The General Structure of the Organs of the Nervous System and their General Functions.

THE nervous system of the human body consists of two great divisions—viz., the *cerebro-spinal* and the *sympathetic* nervous system.

The organs composing the *cerebro-spinal* nervous system are :

1. The central organs, viz., the *brain* and *spinal cord*, which contain as their essential structure the *nerve-centres*.

The organs composing the *sympathetic* nervous system are:

1. The *ganglia*, which are its central organs, containing the centres.
2. The *nerves* which connect these centres and pass to and from them.

A. The General Structure of the Central Organs of the Nervous System.

The central organs of the nervous system are composed of two structures, called the gray and the white nerve substance.

The Gray or Vesicular Nerve Substance.—This structure has, as the name implies, a grayish color. It is composed of nerve-cells, delicate fibrillæ, and of a mass, called the *neuroglia*, which supports these elements.

The *nerve-cells, nerve-vesicles*, or *ganglionic cells* are composed of a reddish, granular protoplasm. They have

no distinct cell-wall, but a clear, round or oval nucleus, with one or more nucleoli. The nerve-cells are from $\frac{1}{500}$ to $\frac{1}{10}$ of a millimetre in diameter, and are either oval, angular, or stellate in form. They have one, two, or several protoplasmic projections from their body, which are called the *poles;* and nerve-cells are called, accordingly, *uni-*, *bi-*, or *multipolar* nerve-cells. These poles either terminate in a point, or anastomose with poles of other nerve-cells, or are continuous as the axis-cylinder of a nerve-fibre.

The second histological elements of the gray nerve substance are the delicate *non-medullated nerve-fibrillæ* which connect the nerve-cells.

The nerve-cells and the fibrillæ connecting them are embedded in a soft, homogeneous mass called *neuroglia.* This consists of connective-tissue fibres of special cells, the glia cells, and of a gelatinous intercellular substance.

The White Nerve Substance of the Central Organs.—This structure has, as the name implies, a whitish color. It consists of nerve-fibrillæ which are composed of the continuation of the poles of the nerve-cells in the gray substance. These fibrillæ are surrounded by a soft mass, the medullary sheath ; like the fibrillæ in the gray substance, these are surrounded by neurilemma.

The essential elements of the central organs of the nervous system are the *nerve-centres.*

The Nerve-Centres, their Distribution, and their General Functions and Properties.—According to their distribution, the nerve-centres or ganglia are divided into :

1. *Central ganglia*—those contained in the central organs.

2. *Spinal ganglia*—those interposed in the course of the peripheral nerves of the cerebro-spinal nervous system.

3. *Sympathetic ganglia*—the centres of the sympathetic nervous system.

The ganglia or nerve-centres are either simple stellate nerve-cells, like the central ganglia, or they are more com-

plicated in structure, like the sympathetic ganglia, which generally consist of pear-shaped unipolar nerve-cells, the pole of which is continuous as the axis-cylinder of a nerve-fibre; delicate fibrillæ from the body of the cell form a second fibre, which passes spirally around the pole of the cell. The spinal ganglia are sometimes unipolar and sometimes bipolar cells.

The General Functions of the Nerve-Centres are: 1. The transmission of impulses to the nerves arising from them.

2. The reception of impulses from the periphery through the nerves arising from them.

3. The transmission, to the nerves passing from them to the periphery, of the impulses which they have received through the nerves from the periphery. This process is termed a *reflex*, and the resulting physiological act is called a reflex act.

Their Special Functions.—The nerves which conduct impressions from the periphery to the centre are (*a*) the nerves of *sensation* and (*b*) the *sensory* nerves. The centres receiving these impressions are called (*a*) the *sensory* centre and (*b*) the *sensible* centres.

The nerves conducting impressions from the centre to the periphery are (*a*) the *motor* nerves, (*b*) the *secretory* nerves, (*c*) the *inhibitory* nerves, and (*d*) *trophic* nerves. The centres from which these nerves receive their impressions are called (*a*) *motor* centres, (*b*) *secretory* centres, (*c*) *inhibitory* centres, and (*d*) *trophic* centres.

According to their special functions the nerve-centres are therefore divided into

1. Sensory.
2. Sensible.
3. Motor.
4. Secretory.
5. Inhibitory.
6. Trophic.
7. Special centres which govern psychical activity.

The various nerve-functions are distributed to the various nerve-centres; none of these can preside over more than one function.

The General Properties of the Nerve-Centres.—The activity of the motor centres—viz., those centres which transmit impulses to the periphery—is excited in various ways; these are:

1. A motor centre may act *automatically*—that means, without any nerve influence from without. The automatic activity of a motor centre may be continuous, or tonic, or intermittent, or rhythmical.

2. The activity of a motor centre may be excited by an effort of the will—that means, it may be *voluntary*.

3. The activity of a motor centre may be excited by a stimulus received through a nerve from the periphery, the impulse being then reflected by the centre to a motor nerve. This process is termed *reflex activity*.

According to the mode in which the activity or impulse was produced in the centre, we distinguish:

(*a*) Automatic and reflex secretion.

(*b*) Automatic and reflex inhibition.

(*c*) Automatic, voluntary, and reflex motion.

The various actions in the body are therefore caused either by an automatic, a voluntary, or a reflex activity of the nerve-centres presiding over the respective functions.

The nervous mechanism for an *automatic* act consists of the nerve-centre and the nerve passing from it to the periphery.

The nervous mechanism for a *voluntary* act includes a normal condition of the nerve-centres which preside over the psychical activity, the nerve-centres presiding over the respective function, and a nerve passing from the centre to the periphery.

The nervous mechanism for a *reflex* act consists of a centripetal nerve which conducts the impulse to the centre from the periphery; the centre which receives and reflects

the impulse to a centrifugal nerve; and the latter, which conducts the impulse from the centre to the periphery.

A reflex act is in itself an involuntary act, but many of the reflex acts in the body are under the control of the will —viz., they can be altered, directed, inhibited, and induced by an effort of the will. Reflex acts may be direct or indirect. A *direct reflex* act is one produced as the immediate result of a peripheral irritation; an *indirect reflex* act, or a *secondary reflex* act, is one which began by an effort of the will—viz., as a voluntary act—but it continued involuntarily, to be finally stopped again or altered by the will. Such acts are walking, writing, the climbing of stairs, etc. These are motions which are started voluntarily, but continued involuntarily without any special voluntary effort.

Reflex motions may be simple or co-ordinated. *Simple reflex* motions are merely the purposeless contractions of one or several muscles, caused by the reflex activity of a motor centre as the result of a peripheral irritation.

The muscular contractions in convulsions, tetanus, hydrophobia, and epilepsy are examples of simple reflex motions.

Co-ordinated reflex motions are those which are produced when the impulse received by the motor centre or centres through centripetal nerves is reflected upon the motor nerves of groups of muscles, the contraction of which causes motions which are intended for a certain purpose. If, for instance, during sleep the sole of the foot is tickled, the foot is drawn up as the result of a reflex motion having for its purpose the withdrawal of the foot from the irritation.

The reflex actions occurring normally in the animal body may be classified, in accordance with their nervous mechanism, as follows:

1. Those in which the centripetal and centrifugal nerves are both cerebro-spinal. Examples: coughing, sneezing, deglutition.

2. Those in which the centripetal is a cerebro-spinal nerve, and the centrifugal a sympathetic nerve. Example: salivary secretion.

3. Those in which both the centripetal and centrifugal nerves are sympathetic nerves. Example: the normal mode of the secretion of the gastro-intestinal juices.

In some abnormal conditions the centripetal nerve, which conveys the stimulus or impulse indirectly to the centre, is a sympathetic, and the centrifugal a cerebro-spinal, nerve. Example: cramps, the spasmodic muscular contractions of the gastro-intestinal walls, produced by the injection of substances which irritate the gastro-intestinal mucous membrane and its sensory nerves. Aside from the general properties of the nerve-centres which I have already described, they also possess the property of conducting, transferring, augmenting, and inhibiting impulses which they receive.

By the property of *conduction* is understood the property of a nerve-centre by which it can conduct to another centre impulses which it has received through a centripetal nerve. If, for instance, food is introduced into the gastro-intestinal canal, its presence irritates the sensory nerves of the mucous membrane; the impulse is conveyed by these sensory nerves, which are of the sympathetic plexus, to the sympathetic ganglia, and it is reflected by these upon the motor and secretory fibres of the gastro-intestinal canal; the result is reflex secretion and reflex motion.

If, now, a substance is introduced with the food into the intestinal canal which greatly irritates the sensory fibres of the mucous membrane, then the impulse is conveyed by the sensory nerve to the sympathetic ganglion or centre, and it is *conducted* by this to centres more distant—viz., to those of the spinal cord and brain; the result is painful cramps.

The property of *transference* consists in the capability of nerve-centres to transfer impulses not only to nerve-fibres which arise from them, but also to adjacent nerve-fibres.

Ordinarily an impulse received by a nerve-fibre at the periphery is conducted by the same uninterruptedly to the centre. If, however, a nerve-centre is interposed in the course of the fibre conducting the impulse, then the same may be transferred by that centre to an adjacent nerve fibre, and the impulse is then carried centrally by that nerve-fibre.

An example of this property of nerve-centres is the pain in the knee-joint experienced as a symptom of hip-joint disease. The disease of the hip-joint produces an irritation of its sensory fibres by which the impulse is conducted toward the centres from which they arise. In the course of these fibres there is interposed a centre or centres by which the impulse is transferred to adjacent fibres—which in this instance are sensory fibres of the knee-joint—and the impulse is then conducted by these to the centres from which they arise; the result is the experience of pain in the knee-joint instead of the hip-joint.

By the property of *augmentation* is meant the property possessed by nerve-centres by which they can increase a stimulus or impulse which they have received.

By the property of *inhibition* is meant the property of nerve-centres by which they can diminish or entirely inhibit an impulse which they have received.

From the foregoing description of the functions and of the properties of nerve-centres, we may recapitulate as follows :

1. The functions of the nerve-centres are to produce (by their activity) motion, secretion, inhibition, sensation, and sensibility. A nerve-centre presides over only one of these functions.

2. The properties of the nerve-centres are : A nerve-centre may act automatically, voluntarily, reflexively, and it may transfer, conduct, augment, or inhibit nerve-impulses. A nerve-centre may possess more than one of these properties.

LECTURE XXXV.

B. THE GENERAL STRUCTURE OF THE NERVES.

A NERVE-TRUNK is composed of nerve-fibres. These are held together in bundles by connective tissue which passes between the individual fibres and then surrounds the bundle. A number of these are again surrounded by connective tissue, forming a nerve-trunk. The connective tissue which passes in between the nerve-fibres is called the *endoneurium;* that surrounding the bundles of nerve-fibres is called the *perineurium;* and that holding the bundles together is called the *epineurium.* These various connective-tissue structures are continuous with each other. The whole nerve-trunk is covered by the nerve-sheath.

The Structure of the Nerve-Fibres.

Nerve-fibres differ in their structure, and are accordingly classified into medullated and non-medullated nerve-fibres.

A *medullated* nerve-fibre consists of three structures—viz., (*a*) an axis-cylinder, (*b*) the medullary sheath, and (*c*) the neurilemma.

(*a*) The *axis-cylinder* is the central portion and the essential element of a nerve-fibre; it is of a gray-reddish color and consists of delicate fibrillæ. The axis-cylinder is continuous with a pole of a nerve-cell; it passes in an *uninterrupted* course from its origin to its termination, *and does not branch.* The axis-cylinder is the *conducting portion* of a nerve-fibre.

(*b*) The medullary sheath, also called the *myeline* sheath or *white substance of Schwann,* is a semi-solid,

soft, fatty substance which surrounds the axis-cylinder; its thickness varies in the various nerve-fibres.

(*c*) The *neurilemma* is a delicate tubular fibrous sheath which surrounds as the external covering many nerve-fibres. In it are seen, at irregular intervals, large oval nuclei surrounded by protoplasmic masses. These bodies are called the *nerve-corpuscles;* they are believed to be remnants of fœtal life.

Not all medullated nerve-fibres are surrounded by neurilemma. It is absent in the nerve-fibres in the central organs and in those of some nerves of special sense. It is also wanting in some fibres of the sympathetic nerves.

Those nerve-fibres which are surrounded by neurilemma, as are all those of the cerebro-spinal and most of the sympathetic nerves, present a varicosed or nodulated appearance. This is due to constrictions of the neurilemma by which, at certain irregular intervals, the continuance of the medullary sheath is interrupted. The nodules produced by this peculiar arrangement are called the *nodes of Ranvier.* Medullated nerve-fibres which have no neurilemma do not have this nodulated, varicosed appearance.

A *non-medullated* nerve-fibre differs from the former in that its axis-cylinder is not surrounded by a medullary sheath; it consequently has a darker color. The non-medullated nerve-fibres of the central organs are not surrounded by neurilemma.

The General Functions and Properties of Nerve-Fibres.

The general function of nerve-fibres is the conduction of impulses. Nerve-fibres conducting impulses from the periphery to a centre are called *afferent* or *centripetal* nerves.

Nerves conducting impulses from a centre to the periphery are called *efferent* or *centrifugal* nerves.

Nerves conducting impulses between centres are called *intercentral* nerves. The *special* function of nerve-fibres is the conduction of impulses of a special character, and the

various nerve-fibres are named accordingly. The *centrifugal* nerves are, according to the character of the impulse they conduct, divided into *motor*, *secretory*, *trophic*, and *inhibitory* nerves.

The *centripetal* nerves are divided, according to the character of the impulse which they conduct, into nerves of *special sense* and *sensory* nerves.

The laws defining and explaining the conduction of impulses in nerve-fibres are, in the principal points, the following:

1. Nerve-fibres normally conduct impulses only in one direction.

2. The direction of the current of an impulse through a nerve-fibre is always longitudinal. The current is isolated and never transmitted laterally.

3. A nerve fibre only conducts impulses of one kind. A motor nerve only conducts motor impulses; a sensory nerve, sensory impulses, etc.

4. The current is transmitted from particle to particle of the nerve-substance.

The rapidity of the conduction of impulses through nerves was formerly believed to be unmeasurable, but *Helmholtz* succeeded in demonstrating, with the use of delicate apparatus, that an impulse in the motor nerve of a frog is conducted with the velocity of 26.4 metres per second. Experiments made in this direction on the human subject showed that the velocity of the conduction of impulses through motor and sensory nerves is from 30 to 60 metres per second.

The cause of the activity of nerve-fibres is the metabolic processes taking place, which result in the transformation of the potential or latent forces contained in the chemical ingredients into living or kinetic forces.

The activity of nerve-fibres is also accompanied by chemical changes.

Nerve-fibre in a *resting* state has an *alkaline*, and in the

active state an *acid* reaction; this is due to the formation of lactic acid.

The general properties of nerve-fibres are: 1. The property of responding to stimuli; it is described as the nervous irritability.

2. The property of inherent natural electrical currents.

1. *Nervous Irritability.*—Nerves possess, like muscles, the property to respond to agents which, when applied, excite their activity. Such agents are called stimuli, and the property of nerves to respond to them, nervous irritability.

The same agents which act as stimulants to muscles also excite the activity of nerves.

The agents which ordinarily excite the activity of nerves are called *natural* or *physiological* nerve stimuli; their exact nature is not fully understood.

Artificial nerve stimuli are agents which excite nerve activity when the nerve is subjected to their influence. They may be classified into mechanical, thermal, and electrical agents. They all produce their effect—viz., to excite nerve activity—by causing greater or less temporary or permanent changes in the nerve-substance.

Electricity is preferable as an agent in the exciting of nerve activity for experimental purposes, as it causes the least changes in the nerve-substance.

Mechanical stimuli are such as a blow, tension, pressure, puncture, or cutting. The activity of a nerve is excited when subjected to such mechanical treatment: this is well shown by the sharp pain experienced when a sensory nerve is suddenly struck a blow, or when, during a minor operation, such a nerve is cut. When a motor nerve is suddenly subjected to a blow, puncture, or cutting, a sudden contraction of the muscle supplied by that nerve will be the result. Mechanical influences only act as nerve stimulants when the nerve is suddenly subjected to them. On the other hand, they may cause a destruction or a diminution of the irritability when the nerve is subjected

to their influence for a longer time. This is well shown by the temporary paralysis, peculiar sensation, and anæsthesia of a part experienced in the condition commonly known as the "falling asleep" of a limb. The condition is produced by pressure of the motor and sensory nerves of that limb.

That continued pressure totally destroys irritability is shown by paralysis produced in certain regions by the pressure of tumors, aneurisms, crutches, etc., upon nerves.

When a nerve is subjected to moderate and short-continued tension its irritability is at first increased. It is for this reason that nerve-tension is employed in the treatment of certain nervous affections, as neuralgias, etc.

Thermal agents—viz., heat and cold—when suddenly applied, act as nerve-stimuli. When a nerve is subjected to their influence for a longer time its irritability is diminished or totally and permanently destroyed. Heat at first increases and then quickly destroys nervous irritability. Cold gradually diminishes the same. This is well shown by the local anæsthesia produced by subjecting a part to the influence of cold for a time.

Chemical agents—such as solutions of mineral and organic acids, alkalies, certain mineral and metallic salts, bile, sugar, alcohol, ether, and chloroform—act as nerve-stimuli and also influence the irritability of nerves.

Electricity applied to a nerve acts as a stimulus, exciting its activity. The influence of an electrical current as a nerve-stimulant is produced most perceptibly when the strength of the electrical current is suddenly altered or when it is frequently interrupted.

Fatigue and *prostration* of a nerve, as shown by a diminished activity, are produced by over-stimulation and by long-continued activity with insufficient periods of rest. Fatigue of a nerve is, like that of a muscle, due to an accumulation of the products of retrogressive metamorphosis. It has been observed that nerve fatigue is produced more

slowly than muscular fatigue. Total inactivity of a nerve also diminishes, and finally destroys, its irritability, as shown by degeneration in paralytic conditions. Certain drugs, such as veratrine, strychnine, etc., influence nervous irritability. They at first increase, and after a long-continued use, diminish, irritability.

2. *The Natural Inherent Electrical Currents in Nerves.* —*Du Bois-Reymond* has demonstrated that in nerves, as in muscles and other structures of the animal body, there exist natural inherent electrical currents. To demonstrate the presence of these the same apparatus is used as is employed to demonstrate the natural electrical currents in muscle tissue—viz., a pair of unpolarized electrodes and a galvanometer.

Not having the time to dwell in detail on the subject of electro-physiology, I will only say that in general the rules and laws governing the natural electrical currents in muscle, and the changes taking place in the electrical condition of a muscle during its activity, as I have briefly explained them in my lectures on muscular motion, also apply to the electrical condition of nerves.

The Chemical Composition and Properties of Nerve-Substance.

Nerve-tissue is composed of (*a*) water, (*b*) albuminous substances, (*c*) albuminoid substances, (*d*) substances resembling fat, (*e*) waste products, and (*f*) inorganic salts.

(*a*) *Water.*—Gray nerve-substance contains 53 to 84 per cent, the white substance 60 to 70 per cent, of water.

(*b*) The *albuminous materials* of the nerve-tissue are contained principally in the protoplasm of the nerve- or ganglion-cells and in the axis-cylinder. The exact nature of these albumins is not known; one of them resembles the myosin of the muscles.

(*c*) The *albuminoid* ingredients of nerve-tissue are:

1. *Neurokeratin.* This is a substance which contains

no phosphorus but is rich in sulphur; it is contained largely in the neuroglia.

2. A substance resembling *elastin* is derived from the myeline sheath.

3. *Gelatin*, derived from the connective tissue of the nerves.

(*d*) Substances which resemble *fats* and are soluble in ether. These are:

1. *Protagon*, constituting the principal ingredient of the brain substance. It contains N, S, and P; it is not contained in nerve- or ganglion-cells.

2. *Lecithin*, a substance which is combined with protagon.

3. *Cerebrin* is considered a decomposition product of protagon; it does not contain P.

4. *Cholesterin*, a hydrocarbonaceous substance.

5. *Oleophosphoric acid*, a decomposition product of lecithin.

(*e*) Products of the *retrogressive metamorphosis* or *dissimilation* of the nerve-substances. These are:

1. Xanthin.
2. Hypoxanthin.
3. Kreatin.
4. Urea.
5. Uric acid.
6. Amidic acid.
7. Acetic acid.
8. Inosit.
9. Taurin.
10. Lactic acid.

(*f*) *Inorganic salts.* These are principally the *chlorides* and *phosphates* of *sodium*, *potassium*, *magnesium*, and *calcium*.

The *reaction* of nerve-tissue in a fresh state is alkaline, but it becomes acid soon after death, which is believed to be due to the formation of lactic acid.

The reaction of nerve-fibres varies in different conditions. It is, like that of the muscular fibres, alkaline or neutral in the resting condition, and acid in the active condition.

After death nerve-tissue becomes and remains for a time firm and stiff, which is believed to be due to processes analogous to those taking place in muscle-tissue in rigor.

The Nutrition and the Metabolism of Nerve-Tissue.

The particles of nerve-tissue derive the materials for their nutrition from the parenchymatous fluid in the tissue, which is supplied by the blood.

Exactly which materials are assimilated is not known. It is believed that the metabolic processes in the nerve-tissue are much less active than in any other, but the abundant vascular supply to the nerve structures, especially to the great centres, and the occurrence of the various products of retrogressive metamorphosis, show the presence of metabolic processes. The importance of these processes is also well demonstrated by the disturbances produced when the vascular supply is interfered with.

The exchange of the gases CO_2 and O has not been demonstrated, but the immediate effect produced on the activity of nerve-structures when the normal exchange of these gases is disturbed in the system, clearly shows that this process is as important for the normal activity of nerve-tissue as for any other structure. It is probable that the exchange of these gases is less active than in other tissues.

The nutrition and also the growth and development of nerves is governed by special centres, which are called the *trophic* centres. The nerve-centre from which a nerve arises is generally its trophic centre. When through injury or disease a nerve is severed from its connection with its trophic centre, then the distal end undergoes degeneration.

A regeneration of nerve-substance by which the cut ends of a nerve reunite, the distal end gradually regaining its functions and properties, takes place under certain circumstances.

The process of regeneration always begins in the central part of the cut nerve.

Nerve-suture, as practised in surgery, is based upon this regenerative power.

LECTURE XXXVI.

THE CENTRAL ORGANS OF THE CEREBRO-SPINAL NERVOUS SYSTEM, THEIR STRUCTURE AND FUNCTIONS.

THE central organs of the cerebro-spinal nervous system are the brain and the spinal cord.

To understand their physiology it is necessary to be familiar with their minute anatomy.

The Brain.

The brain is that portion of the cerebro-spinal axis contained in the cranial cavity. The different structures composing the brain are covered by three membranes, called the dura mater, the arachnoid, and the pia mater.

The *dura mater* is a tough, dense, fibrous membrane. It forms the outer covering of the brain, and is adherent to the inner surface of the cranial bones, forming their periosteum.

The inner surface of the dura mater is lined with flat endothelial cells.

The *arachnoid* forms the middle covering of the brain. It is a delicate membrane composed of fibrous and areolar tissue; its outer surface is covered with flat epithelial cells. The space between the under surface of the dura mater and the outer surface of the arachnoid is called the *subdural* space; this is a serous cavity and contains serous fluid.

The *pia mater* is a delicate vascular membrane which is closely adherent to the outer surface of the brain and sends prolongations into the fissures on its surface. The pia mater also sends a prolongation, known as the *velum inter-*

positum, into the interior of the general ventricular cavity of the cerebrum through its transverse fissure.

The outer surface of the pia mater is connected by fibrous trabeculæ with the arachnoid. The space between these two membranes is called the *subarachnoidian* space, and also contains serous fluid.

The dura mater sends three prolongations into the cranial cavity, which pass between the various structures of the brain. These processes are the falx cerebri, the falx cerebelli, and the tentorium cerebelli.

The *falx cerebri* passes into the longitudinal fissure between the two cerebral hemispheres.

The *falx cerebelli* passes into the fissure between the two cerebellar hemispheres.

The *tentorium cerebelli* passes between the under surface of the occipital lobes of the cerebrum and the upper surface of the cerebellum.

The function of the membranes of the brain is to protect it. The presence of serous fluid in the subdural and the subarachnoidian space protects the brain from the effects of concussion or external violence. The pia mater serves to support blood-vessels for the supply of the brain.

The *weight* of the brain divested of its membranes is 49 ounces or 1,570 grammes in the male, and 44 ounces or 1,420 grammes in the female. These weights are not the absolute, but average weights.

The various parts composing the brain are: the cerebrum, the cerebellum, the pons Varolii, and the medulla oblongata.

The Cerebrum.

The cerebrum is the largest portion of the brain. It occupies the whole anterior and middle, and a large portion of the posterior, part of the cranial cavity.

The cerebrum presents for examination an outer, exterior, or upper surface, an under surface or base, and its interior.

The Outer, Exterior, or Upper Surface of the Cerebrum.—This surface is directed toward the concave roof of the cranial cavity; it is convex from side to side and from the front backward. The outline of the circumference of the cerebrum is oval, being longer in the antero-posterior than in the lateral diameter, and somewhat narrower in front than behind.

The cerebrum is divided by a fissure, called the *longitudinal* fissure, into halves called the *hemispheres*.

The great longitudinal fissure passes from the front backward along the middle line of the cerebrum. On the upper surface this fissure separates the two hemispheres completely. On the under surface, or base, this fissure only separates the hemispheres completely anteriorly and posteriorly, while in the middle they are connected by a transverse band of white nerve-substance called the *great transverse commissure* or the *corpus callosum* of the cerebrum. The upper surface of this is seen in the bottom of the superior longitudinal fissure when the hemispheres are held apart.

Each *cerebral hemisphere* presents for examination an outer, an under, and an internal surface.

The *outer* surface forms one lateral half of the outer surface of the whole cerebrum. It is convex from the front backward and from side to side; it is directed toward the concave interior of one-half of the roof of the cranial cavity.

The *under* surface forms one lateral half of the base of the cerebrum. It is irregular in form and rests anteriorly in the anterior fossa of the cranial cavity, with its middle portion in the middle fossa, and with its posterior portion on the upper surface of the cerebellum on its respective side.

The *inner* surface is flat. It is directed toward the inner surface of the cerebral hemisphere, on the other side, and forms the lateral wall of the longitudinal fissure.

These surfaces of the cerebral hemispheres present various longitudinal furrows of a greater or less depth. They pass in an apparently irregular course in different directions on the surfaces of the cerebral hemispheres, giving them a lobulated and convoluted appearance. These furrows are divided into fissures and sulci.

The *fissures* are deep furrows which penetrate into the substance of the cerebral hemispheres, dividing it into portions called the *lobes*. The fissures are formed during the development of the cerebrum, by an involution of its mass.

They are constant and are the same, as regards their position, course, and arrangement, in all brains of the same species.

The cerebral hemispheres of the human brain present three fissures—namely, the fissure of Rolando, the fissure of Sylvius, and the occipito-parietal fissure.

The *fissure of Rolando* begins at the upper border of the superior longitudinal fissure, at about its centre; it then passes downward and slightly forward on the outer surface of the cerebral hemisphere, terminating a little above the horizontal limb of the fissure of Sylvius and a little behind the ascending limb of the same fissure. The fissure of Rolando divides the cerebral hemisphere on its outer surface into two lobes—one anterior to the fissure, called the *frontal* lobe, and one posterior to the fissure. This part is again divided into lobes by other fissures. That portion directly behind the fissure of Rolando is termed the *parietal* lobe.

The *occipito-parietal fissure* begins at the lower border of the longitudinal fissure posteriorly, then passes upward along the inner surface of the cerebral hemisphere, and then downward and forward for about an inch on the outer surface.

This fissure separates, on the inner and outer surface, a portion from the parietal lobe; this posterior portion is called the *occipital* lobe.

The *fissure of Sylvius* begins at the under surface of the cerebral hemisphere, near the centre. From there the fissure passes outward toward the outer borders, and, winding around this to the outer surface, it divides it into two. One, the *ascending limb*, passes upward on the outer surface, terminating in front of the lower end of the fissure of Rolando. The other, the *horizontal limb*, passes for a short distance upward on the outer surface, and then horizontally backward, and separates a portion from the lower part of the parietal lobe: this is called the *temporo-sphenoidal* lobe.

These three fissures—viz., the fissure of Rolando, the occipito-parietal fissure, and the fissure of Sylvius—divide each cerebral hemisphere into *four* lobes, called the frontal, parietal, occipital, and temporo-sphenoidal lobe.

The *frontal* lobe is that portion which is situated in front of the fissure of Rolando.

The *parietal* lobe is the portion behind the fissure of Rolando, in front of the occipito-parietal fissure, and above the horizontal limb of the fissure of Sylvius.

The *occipital* lobe is the portion posterior to the occipito-parietal fissure.

The *temporo-sphenoidal* lobe is the portion beneath the horizontal limb of the fissure of Sylvius.

On the *outer* surface of the cerebral hemisphere are seen the outer surfaces of the frontal, the parietal, the occipital, and the temporo sphenoidal lobes.

On the *inner* surface of the cerebral hemisphere are seen the inner surfaces of the frontal, the parietal, and of the occipital lobe.

On the *under* surface of the cerebral hemisphere are seen: (1) The under surface of the frontal lobe—viz., that portion of the under surface of the hemisphere which is anterior to the fissure of Sylvius—this is also called the *anterior* lobe: (2) the under surface of the temporo-sphenoidal lobe—this is also called the *middle* lobe: and (3) the

under surface of the occipital lobe—viz., that portion of the under surface of the hemisphere which is in contact with a lateral half of the upper surface of the cerebellum (this is also called the *posterior* lobe).

In the fissure of Sylvius, at the base of the hemisphere, there is a fifth lobe, called the *central* lobe, or the *island of Reil.* This is visible only when the fissure of Sylvius is held apart at the base.

The island of Reil is a triangular-shaped mass which is separated from the frontal, parietal, and the temporo-sphenoidal lobes by three short, deep fissures or sulci, called the anterior, external, and posterior sulcus of Reil.

The *anterior sulcus of Reil* separates the island of Reil from the posterior orbital convolution, from the anterior lobe, or the under surface of the frontal lobe in front.

The *external sulcus of Reil* separates the island of Reil from the inferior part of the inferior frontal, the ascending frontal, and the ascending parietal convolution.

The *posterior sulcus* or *fissure of Reil* separates the island of Reil from the temporo-sphenoidal lobe which is posterior to this sulcus.

The *sulci* are shallow, longitudinal furrows which pass over the surfaces of the cerebral lobes in various directions and branch in their course, and which give to the surfaces of the cerebral lobes a convoluted appearance. The sulci are not constant anatomical points. They are not equally present, and not equally developed, as regards their course, depth, and general arrangement, in all brains of one species. The sulci develop and become more marked as the intelligence and psychical functions of the individual develop.

The exterior of the cerebral hemispheres consists of a layer of gray nerve-substance, which is called the *cortex* of the hemisphere, in contradistinction to its interior white nerve-substance which is called the *medullary* portion.

The cortical gray substance of the cerebral hemispheres

is regarded as the seat of intelligence and the higher psychical functions, and the purpose of the sulci and fissures is to increase the surface for the development of the cortical gray substance without an increase of the surface of the cerebrum itself. The cortical gray substance also covers the sides and floor of the sulci, and the surface is therefore greater when the sulci are well marked, deep, and long than when they are not well developed. It is, for instance, well known that the sulci on the cerebral surface of the brains of cretins and idiots are not well developed. This is the case in animals, apes, dogs, etc.

The protruding convex masses between the sulci are called the *convolutions*.

I will describe only some of the more prominent and constant sulci and convolutions of the cerebral lobes, a knowledge of which is essential, as they are anatomical points important in the localization of the seats of the various functions.

The more prominent sulci and convolutions on the surface of the cerebral hemispheres are:

(*a*) *Those of the Frontal Lobe.*—The *outer* surface of the frontal lobe presents three sulci—viz., the *pre-central* sulcus, which runs parallel with, and a little in front of, the fissure of Rolando; and the *superior* and *inferior frontal* sulci, which divide the portion in front of the pre-central sulcus into three horizontal convolutions, named respectively the superior, middle, and inferior frontal convolution.

The *superior frontal* convolution is that portion of the outer surface of the frontal lobe which is situated above the superior frontal sulcus and in front of the pre-central sulcus.

The *middle frontal* convolution is that portion which is situated between the superior and inferior frontal sulci and in front of the pre-central sulcus.

The *inferior frontal* convolution is that portion of the frontal lobe which is situated beneath the inferior frontal sulcus and in front of the pre-central sulcus.

That portion of the frontal lobe which is situated behind the pre-central sulcus and in front of the fissure of Rolando is called the *ascending frontal convolution.*

The *inferior* surface of the frontal lobe is that portion of the base of the cerebral hemisphere which is situated anteriorly to the fissure of Sylvius; this portion is also called the *orbital* or the *anterior lobe.* It rests upon the orbital plate of the frontal bone.

This surface presents two sulci—viz , the orbital and the olfactory sulci.

The *olfactory* sulcus or fissure is a deep furrow which begins in front of the optic commissure and passes forward to nearly the anterior border of the frontal lobe, parallel with and a little external to the anterior portion of the longitudinal fissure. The narrow convolution internal to this sulcus is the under margin of the marginal convolution of the internal surface of the hemisphere.

The portion of the orbital lobe external to the olfactory sulcus is divided by the *optic* sulcus, which passes transversely and has several rami, or minor sulci, passing from it in various directions.

The three lobes into which this portion is thus divided are called respectively the *internal*, the *anterior*, and the *posterior orbital* convolutions.

That portion of the cerebral hemisphere which forms the roof of the fissure of Sylvius is composed of the inferior part of a small portion of the inferior frontal convolution, of the lower portions of the ascending frontal and of the ascending parietal convolution, and of the triangular mass known as the island of Reil.

The surface which is made up of the convolutions just mentioned presents three marked, distinct, and several minor sulci. The three marked sulci are the anterior, the posterior, and the external sulcus of Reil.

The *anterior sulcus* or *fissure of Reil* separates the posterior orbital convolution from the island of Reil.

The *external sulcus* or *fissure of Reil* separates the under portion of the inferior orbital, the ascending frontal, and the ascending parietal convolution from the island of Reil.

The *posterior sulcus of Reil* separates the island of Reil from the mass of the temporo-sphenoidal lobe.

The surface of the island of Reil is divided by minor sulci into several lobes or convolutions, which are called *gyri operti*.

(*b*) *The Sulci and Convolutions of the Parietal Lobe.*—The surface of the parietal lobe has two sulci—viz., the intraparietal and the post-central sulcus.

The *intraparietal* sulcus begins a little posteriorly to the lower end of the fissure of Rolando. It then ascends vertically for a short distance, and finally curves backward, terminating at the border of the longitudinal fissure a little in front of the external occipito-parietal fissure.

The *post-central* sulcus is continuous with the ascending portion of the intraparietal, and ascends from it to the border of the longitudinal fissure, running parallel with and a little posteriorly to the upper part of the fissure of Rolando.

These two sulci divide the outer surface of the parietal lobe into three convolutions—viz., the ascending, the superior, and the inferior parietal convolutions.

The *ascending parietal* convolution is that portion which is situated in front of the ascending part of the intraparietal sulcus and the post-central sulcus and behind the fissure of Rolando.

The *superior parietal* convolution is the portion above the covered part of the intraparietal sulcus and behind the post-central sulcus.

The *inferior parietal* convolution consists of two portions—an anterior which is called the *supramarginal* portion, and a posterior which is called the *angular* portion; the two are divided by a shallow sulcus. The supramarginal portion is bounded in front by the lower part of the

fissure of Rolando, being connected here with the ascending parietal convolution; below, it is bounded by the horizontal limb of the fissure of Sylvius; above, by the intraparietal sulcus; and anteriorly it is continuous with the angular portion.

The angular portion is connected in front with the supramarginal portion; above, it is bounded by the intraparietal sulcus; behind, it is connected with the second annectant gyrus, which is a portion of the middle occipital convolution ; below, it is connected with the middle temporo-sphenoidal convolution.

(*c*) *The Sulci and Convolutions of the Occipital Lobe.*—The outer surface of the occipital lobe is divided by two indistinctly marked sulci into three convolutions. The sulci are the superior and middle occipital sulci.

The *superior occipital* sulcus curves upward along the posterior part of the lobe ; it is continuous above with the backward-curving portion of the intraparietal sulcus ; below, it joins the horizontally running middle occipital sulcus.

The *middle occipital* sulcus begins at the inferior border of the occipital lobe, and then passes obliquely upward and backward, joining the superior occipital sulcus.

The occipital lobe is divided by these two sulci into three convolutions, named respectively the superior, the middle, and the inferior occipital convolutions.

The *superior occipital* convolution is the portion above the superior occipital sulcus. This portion is connected with the superior parietal convolution by a process which is called the first *annectant gyrus.*

The *middle occipital* convolution is the portion between the superior and middle occipital sulci. This portion is connected in front and above with the angular portion of the inferior parietal convolution by a process which is called the *second annectant gyrus.* Below and in front the middle occipital convolution is connected with the

middle temporo-sphenoidal convolution by another process, which is called the *third annectant gyrus.*

The *inferior occipital* convolution is the portion below the middle occipital sulcus. This portion is connected in front with the inferior temporo-sphenoidal convolution by a process called the *fourth annectant gyrus.*

(*d*) *The Sulci and Convolutions of the Temporo-Sphenoidal Lobe.*—The surface of the temporo-sphenoidal lobe is divided by two sulci into three convolutions. The sulci are the superior and inferior temporo-sphenoidal fissure or sulcus.

The *superior temporo-sphenoidal* sulcus runs a little below and parallel with the horizontal limb of the fissure of Sylvius.

The *inferior temporo-sphenoidal* sulcus runs a little below and parallel with the former. These two sulci divide the outer surface of the temporo-sphenoidal lobe into three convolutions, called the superior, middle, and inferior temporo-sphenoidal convolutions.

The *superior temporo-sphenoidal* convolution is the portion between the horizontal limb of the fissure of Sylvius and the superior temporo-sphenoidal sulcus. Posteriorly this convolution is connected with the supramarginal portion of the inferior parietal convolution.

The *middle temporo-sphenoidal* convolution is the portion between the superior and inferior temporo-sphenoidal sulci. This convolution is connected behind with the angular portion and with the third annectant gyrus of the middle occipital convolution.

The *inferior temporo-sphenoidal* convolution is the portion below the inferior temporo-sphenoidal sulcus. This portion is connected behind with the fourth annectant gyrus of the inferior occipital convolution.

The *inner* surface of the cerebral hemisphere is also divided by sulci into convolutions.

This surface presents five well-marked fissures—viz.,

the calloso-marginal, the parieto-occipital, the calcarine, the collateral, and the dentate.

The *calloso-marginal* fissure begins beneath the curved anterior end of the corpus callosum ; it then curves forward and upward over the anterior end, and then curves backward, and finally passes upward, terminating at the upper border of the internal surface a little behind the beginning of the fissure of Rolando. In its course the calloso-marginal fissure runs parallel with the curved anterior end and the rostrum or upper surface of the corpus callosum, dividing that portion of the internal surface of the hemisphere which is located beneath and in front of the anterior end, and above the rostrum of the corpus callosum, into two convolutions, which are called the marginal convolution and the gyrus fornicatus, or the convolution of the corpus callosum.

The *marginal* convolution is the portion above or external to the calloso-marginal convolution. The surface presents several minor sulci.

The *gyrus fornicatus*, also called the *convolution of the corpus callosum*, is the portion between the calloso-marginal fissure and the upper border of the anterior end and upper surface of the corpus callosum.

The *occipito-parietal* fissure begins a little behind and on a level with the splenium, or posterior end of the corpus callosum. This fissure passes from this point obliquely backward and upward, and is continuous at the upper border of the internal surface with the external parieto-occipital fissure.

That portion of the internal surface which is situated between this internal parieto-occipital fissure and the ascending part of the calloso-marginal fissure is called the *quadrate* lobe.

The *calcarine* fissure begins at the same point where the internal portion of the parieto-occipital fissure begins. It passes from this point obliquely backward and downward.

The triangular portion of the internal surface between the parieto-occipital fissure above and the calcarine fissure below is called the *cuneate* lobe.

The *collateral* fissure begins beneath the calcarine fissure; it runs parallel with the latter and then continues forward, terminating near the beginning of the fissure of Sylvius. This fissure divides that portion of the internal surface which is located beneath the calcarine fissure and beneath the corpus callosum into two long convolutions, called the uncinate or internal occipito-temporal convolution, and the external occipito-temporal convolution.

The *uncinate* or *internal occipito-temporal* convolution is the portion above the collateral fissure. This convolution is bounded above by the calcarine and the dentate fissures.

The *external occipito-temporal* convolution is that part beneath the collateral fissure. This convolution is separated from the inferior temporo-sphenoidal convolution by the inferior temporo-sphenoidal sulcus or fissure.

The *dentate* fissure is situated above, and runs parallel with, the anterior portion of the uncinate convolution. The fissure begins at the posterior end of the corpus callosum and terminates in front at the curved end of the uncinate convolution.

The internal surface is divided, by the arrangement of these five fissures, into six convolutions—namely, the marginal convolution, gyrus fornicatus, quadrate lobe, cuneate lobe, uncinate convolution, and external occipito-temporal convolution.

LECTURE XXXVII.

THE CEREBRUM (*continued*).

The Under Surface, or Base, of the Cerebrum.

THE base of the cerebrum presents for examination the under surface of the cerebral hemispheres and the parts which are placed along the middle line.

The under surface of each cerebral hemisphere is divided into three lobes—the anterior, middle, and posterior.

The *anterior* or *orbital* lobe is that part of the under surface of the frontal lobe which is situated anteriorly to the fissure of Sylvius. It rests upon the orbital plate of the frontal bone. The fissures, sulci, and convolutions of this lobe I have already described.

The *middle* lobe rests in the middle fossa of the cranium; it is the portion posterior to the fissure of Sylvius.

The posterior lobe of each cerebral hemisphere is that part of the under surface of the cerebrum which is covered by the cerebellum behind and by the pons Varolii in front of this.

If the cerebellum and the pons are raised, it will be seen that the two posterior lobes are completely separated posteriorly by the longitudinal fissure, while anteriorly a portion of the under surface of the posterior end or splenium of the corpus callosum is seen between the two lobes. The parts which are arranged along the middle line between the two hemispheres are:

1. The crura cerebri.
2. The optic tracts and the optic commissure.
3. The parts filling the interpeduncular space.
4. The anterior perforated space.
5. The olfactory tracts and their bulbs.

1. The *crura cerebri* are two broad bands which emerge from the anterior border of the pons Varolii and diverge, passing forward and outward, and then enter the substance of the middle lobes of the cerebral hemisphere. Each crus consists of an upper layer of longitudinal fibres, which is called the *tegmentum;* its fibres are sensory, continuous with the longitudinal fibres of the pons. Beneath this there is a layer of gray nerve-substance which is called the *locus niger*. Again beneath this is a third layer, called the *crusta;* it is the inferior layer and is composed of longitudinal fibres which are continuous with the longitudinal fibres of the pons; they are motor fibres.

From a groove on the inner border of the crura cerebri, near the anterior border of the pons, emerge the fourth pair of cranial nerves. From a groove on the outer border of the crura, near the anterior border of the pons, emerge the third pair of cranial nerves.

2. The *optic tracts* are two white, flattened bands which emerge from beneath the outer border of the crura cerebri a little anteriorly to the third cranial nerves. These bands wind around the outer border and then cross obliquely the under surface of the crura; they converge as they pass forward and inward, and finally meet anteriorly; their junction is called the *optic commissure.*

3. The *interpeduncular space* is the lozenge-shaped space bounded by the anterior border of the pons and the inner borders of the diverging crura cerebri behind, and by the optic commissure and the converging optic tracts in front.

This space is filled with certain structures, which, beginning posteriorly, are as follows:

The posterior perforated space.
The corpora albicantia.
The tuber cinereum.
The infundibulum.
The pituitary body.
The lamina cinerea.

The *posterior perforated space* is a small mass of gray substance placed immediately in front of the anterior border of the pons between the diverging crura. This mass is perforated by minute openings for the transmission of small, straight vessels.

The upper surface of this mass forms part of the floor of the third ventricle.

The *corpora albicantia* are two small, rounded bodies. They are placed side by side in front of the posterior perforated space, and are connected by a commissure. They consist of gray nerve-substance internally and white matter externally.

The *tuber cinereum* is a mass of gray substance placed in front of the corpora albicantia and behind the optic commissure; its upper surface forms a part of the floor of the third ventricle.

The *infundibulum* is a small tubular process from the inferior surface of the tuber cinereum; attached to this is the *pituitary body,* a small glandular organ which rests in the sella turcica; it communicates through the infundibulum with the third ventricle.

The *lamina cinerea* is a mass of gray nerve-substance placed in front of the tuber cinereum and above the optic commissure; laterally it communicates with the anterior perforated space on each side.

4. The *anterior perforated space* is a small, perforated mass of gray nerve-substance which corresponds to a small portion of the under surface of the corpus striatum. It is seen on either side of the optic commissure, filling the small triangular space which is bounded internally and behind by the optic commissure and optic tract, externally by the border of the middle lobe, and anteriorly by the optic lobe.

5. *The olfactory tracts and their bulbs.* The olfactory tracts are two bands of white nerve-substance; they arise from three roots in the anterior perforated space on each side, and pass forward along the under surface of the

frontal lobe, parallel with and near the longitudinal fissure.

Near the anterior border of the frontal lobes the olfactory tracts terminate in bulbous expansions called the *olfactory bulbs*, from which arise the olfactory nerves; these enter the foramina of the cribriform plates of the ethmoid bone.

Immediately in front of the optic commissure a small portion of the anterior end or genu of the corpus callosum is seen between the frontal or anterior lobes. Anteriorly to this these lobes are completely separated by the longitudinal fissure.

The Interior of the Cerebrum.

The interior of each cerebral hemisphere is composed of white nerve-substance and of separate masses of gray matter; in the middle the two cerebral hemispheres are connected by the great transverse commissure or corpus callosum.

The *corpus callosum* is a mass composed principally of transverse nerve-fibres, which are placed between and connect the two hemispheres. It is about four inches long, is located in the longitudinal fissure, and extends forward to within 1½ inches of the anterior border of the cerebrum

The corpus callosum is arched in form. Its upper, convex border or rostrum forms the central part of the floor of the superior longitudinal fissure, and is plainly seen when the two hemispheres are held apart. Its lower surface or border is concave, is directed toward the base of the cerebrum, and forms the roof of the general ventricular cavity.

Anteriorly the corpus callosum terminates in a round mass called the *genu;* this arches downward, so that its lower surface is seen anteriorly between the two frontal lobes at the base of the cerebrum. Posteriorly the corpus callosum terminates in a broad, rounded mass called the *splenium;* this arches downward, so that its under surface

is seen between the two occipital or posterior lobes at the base of the cerebrum.

If from the upper surface of the cerebrum a section is made *above* the upper border of the corpus callosum, it will be seen that each cerebral hemisphere consists of an oval central mass of white nerve-substance surrounded by a margin of gray matter of nearly uniform thickness.

The central oval white mass is termed the *centrum ovale minus;* the gray margin is called the *cortex.* If from the upper surface of the cerebrum another section is made which includes part of the upper border of the corpus callosum, it will be observed that this is a transverse mass of white substance which connects the two hemispheres. The whole white central mass of the cerebrum which is now exposed is called the *centrum ovale majus.* If from the upper surface of the cerebrum still another section is made which includes the upper portion of the corpus callosum, a cavity is exposed which is bounded anteriorly and behind by the ends of the corpus callosum; laterally this cavity extends into the substance of the cerebral hemispheres, and is bounded by masses of gray nerve-substance which are known as the *large basal ganglia* of the cerebrum. The floor of this cavity is formed by the structures filling the interpeduncular space. This cavity is called the *general ventricular cavity* of the cerebrum.

The Basal Ganglia.

The various collections of gray nerve-substance which are located along the middle line of the base of the cerebrum, and those which are contained in the cerebral hemispheres near their inferior surface, are called the *basal ganglia.*

These are: the corpora striata, the optic thalami, the corpora quadrigemina, and the corpora geniculata; the locus niger, the middle layer or gray substance of the crura cerebri, may also be included among them.

The *corpora striata* are masses of gray nerve-substance in the cerebral hemispheres. The corpus striatum in each cerebral hemisphere consists of two separate masses called the nucleus caudatus and the nucleus lenticularis.

The *nucleus caudatus* is a pear shaped mass which is contained in the hemisphere, a little externally and below the upper part of the corpus callosum, which forms the roof of the general ventricular cavity.

The anterior broad extremity is directed forward and its upper surface forms a part of the floor of the main cavity of the lateral ventricle. The posterior tapering end is directed backward and slightly outward, overlapping the optic thalamus, which is located posteriorly and a little internally to the nucleus caudatus.

The nucleus caudatus is also termed the intraventricular portion of the corpus striatum, from the fact that it enters into the formation of the walls of the general ventricular cavity.

The *nucleus lenticularis* is the larger of the two portions of the corpus striatum. It does not participate in the formation of the walls of the general ventricular cavity, and is therefore termed the extraventricular portion of the corpus striatum. This portion is separated from the nucleus caudatus, which is situated internally to it, by a narrow bundle of nerve-fibres known as the *internal capsule*.

The *optic thalami* are two large, oval masses, one in each cerebral hemisphere, located behind and internally to the posterior thin end of the nucleus caudatus; from this it is separated by a narrow, rounded band of nerve-fibres called the *tænia semicircularis*.

The *inner* surface of the optic thalamus forms a part of the lateral walls of the third ventricle. Its *upper* surface is directed toward the floor of the central cavity of the lateral ventricle, and terminates in front in a rounded prominence called the *anterior tubercle*. Its *under* surface rests upon the side of the tegmentum of the crus cerebri.

Its posterior end is projected above the corpora quadrigemina and the pineal gland. Projected from the outer side of the posterior end are two rounded masses called the *corpora geniculata.*

The *corpora quadrigemina* are four round masses—an anterior pair, called the *nates*, and a posterior pair, called the *testes.* These are separated on their superior surface by a transverse and longitudinal furrow.

The corpora quadrigemina are situated beneath the lower surface of the posterior end of the corpus callosum, behind the posterior commissure of the third ventricle, and above the upper surface of the crura cerebri.

Between the under surface of the corpora quadrigemina and the upper surface of the crura cerebri there is a narrow descending channel by which the third ventricle communicates with the fourth ventricle behind and below; this channel is called the *aqueduct of Sylvius.* Laterally the corpora quadrigemina are connected with the sides of the tegmentum of the crura cerebri. Posteriorly from the nates two bands are projected by which the corpora quadrigemina are connected with the cerebellum behind and below; these bands are known as the *processus ad testes.* Above and in front of the nates, and behind the posterior commissure of the third ventricle, is situated a small oval mass—the *pineal gland.*

The *corpora geniculata* are the two rounded masses at the outer surface of the posterior end of the optic thalami.

The General Ventricular Cavity of the Cerebrum.

This cavity, as I have already stated, is bounded *above* by the under surface of the corpus callosum; *laterally* by the cerebral mass in its upper part and by the optic thalami in the lower part; *below* by the structures contained in the interpeduncular space. This cavity is divided by a horizontal partition into an upper and lower part. The horizontal partition is formed by the *fornix* and the *velum interpositum.*

The *fornix* is a flat lamella of white matter which is projected horizontally into the general ventricular cavity a little beneath the under surface of the corpus callosum. The fornix is shaped like an elongated leaf. Its thin, tapering portion is directed backward toward the posterior part of the under surface of the corpus callosum, with which it is connected. The broad anterior portion, which is termed the *body* of the fornix, is projected horizontally forward into the general ventricular cavity, dividing it imperfectly into an upper and lower compartment. From the anterior border of the body of the fornix two flat, narrow bands are projected forward, which are called the *anterior crura of the fornix.* These pass forward and arch downward into the lower part of the general ventricular cavity, which is called the *third ventricle.* They pass down through the space between the genu of the corpus callosum in front and the anterior extremity of the optic thalami and the anterior commissure of the third ventricle behind. Descending to the third floor of the ventricle, they suddenly turn, forming the two rounded masses, called the corpora albicantia, which are seen at the base of the brain in the interpeduncular space. From these the fibres of the anterior crura ascend and enter the substance of the optic thalami at the inner surface.

Between the anterior crura of the fornix and the anterior end of the optic thalamus on each side there is an opening by which each lateral half of the upper portion of the general ventricular cavity communicates with the lower portion—viz., with the third ventricle. This opening on each side is called the *foramen of Monro.*

The posterior tapering end of the fornix, as it passes backward toward the posterior part of the under surface of the corpus callosum, also divides into two lateral bands, which are called the *posterior pillars of the crura of the fornix.* These diverge and pass backward and outward; their posterior end then descends into the descending horns

of the lateral ventricles, forming part of their floor. The edges of the posterior crura are called the *corpus fimbriatum.* The triangular space between the diverging posterior crura behind the body of the fornix is termed the *lyra;* it is filled with the velum interpositum.

The *velum interpositum* is a prolongation of the pia mater. It enters the general ventricular cavity through the narrow space between the under surface of the posterior end or splenium of the corpus callosum and the upper surface of the corpora quadrigemina and the pineal gland. In the general ventricular cavity this prolongation of the pia mater expands horizontally along the under surface of the fornix. The edges of the velum interpositum are highly vascular and present small villous projections; this is termed the *choroid plexus.* It passes forward between the edge of the fornix and the optic thalamus, forming a part of the floor of the central cavity of the lateral ventricle on each side. Posteriorly the choroid plexus descends into the middle horn of the lateral ventricle on each side, forming a part of the floor.

The general ventricular cavity is thus completely divided into an upper and lower compartment by the fornix and the velum interpositum just described.

The upper portion of the general ventricular cavity is again divided into lateral halves, called the lateral ventricles, by a vertical septum which is called the septum lucidum.

The *septum lucidum* is, as I have just stated, a vertical septum which separates the two lateral ventricles from each other. This septum consists of two layers of a thin membrane, which is attached below to the upper surface of the fornix, in front to the reflected portion of the genu of the corpus callosum, above to the under surface of the corpus callosum.

The Fifth Ventricle.—The interval between the two layers of the septum lucidum is called the fifth ventricle.

This cavity is not lined with epithelium and does not communicate with the other parts of the general ventricular cavity.

The Lateral Ventricles.—The cavities lateral to the septum lucidum, and above the fornix and the velum interpositum, are called the lateral ventricles. They are *serous cavities*, lined by a thin membrane covered with a layer of ciliated epithelium; this membrane is called the *ependyma*. The lateral ventricles contain serous fluid. Each lateral ventricle consists of a central cavity and three smaller cavities or cornua, which are called the anterior, posterior, and middle or descending cornu or horn.

The *central cavity* of the lateral ventricle is triangular in form; its roof is formed by the under surface of the corpus callosum, its *inner* wall by the septum lucidum, its *floor* by various structures which pass backward and may be enumerated as follows: the upper surface of the nucleus caudatus of the corpus striatum; the tænia semicircularis; the upper surface of the optic thalamus; the choroid plexus of the velum interpositum; the fornix, and a part of the corpus fimbriatum, or edge of the posterior crus of the fornix on that side.

The *anterior cornu* of the lateral ventricle is triangular, and passes from the central cavity forward and outward into the substance of the frontal lobe. It is bounded *above* by the under surface of the corpus callosum; *externally* by the caudate nucleus of the corpus striatum; and *internally* and in *front* by the reflected portion of the anterior end of the corpus callosum.

The *posterior cornu* of the lateral ventricle is also triangular and pointed; it passes backward in the occipital lobe; its direction is backward, outward, and then inward.

The inner wall of the posterior cornu is formed by a longitudinal elevation called the *hippocampus major*. This elevation is formed by the extension of the calcarine sulcus which is seen on the lower part of the inner surface of the

cerebral hemisphere. The walls of this cavity are formed by the substance of the occipital lobe of the cerebral hemisphere.

The *descending cornu* of the lateral ventricle passes downward around the posterior end of the optic thalamus into the substance of the middle lobe of the cerebral hemisphere.

The descending horn is triangular and pointed; it extends backward, outward, and downward, and curves forward and inward, its point terminating close to the fissure of Sylvius. Its *roof* is formed by transverse fibres of the corpus callosum, and its *sides* by the mass of the temporo-sphenoidal lobe. Its *floor* is formed by the following structures: the hippocampus major; the pes hippocampi; the eminentia collateralis; the corpus fimbriatum of the posterior crus of the fornix; the choroid plexus of the velum interpositum; the fascia dentata, and the transverse fissure.

The *hippocampus major* is, as I have already stated, an elevation produced by an extension of the calcarine sulcus.

The *pes hippocampi* is the lower end of this elevation; it presents several furrows, so that it resembles an animal's paw.

The *eminentia collateralis*, or *pes accessorius*, is an elevation seen at the junction of the middle and the posterior horn.

The *fascia dentata* is a serrated band of gray substance placed between the choroid plexus and the corpus fimbriatum.

The *transverse fissure* is horseshoe-shaped; it passes from the apex of the descending horn of the lateral ventricle on one side to that on the other side.

This fissure passes from the apex of the middle horn upward and backward, and then horizontally across to the other side, and on that side again forward and downward to the apex of the middle horn of the other side.

The portion of the fissure which passes from the apex of

the horn upward and backward is bounded above by the optic thalami, below by the corpus fimbriatum of the posterior crus of the fornix.

The horizontal portion of the fissure is bounded above by the under surface of the posterior end of the corpus callosum, and below by the posterior surface of the corpora quadrigemina. Through this fissure prolongations of the pia mater enter the general ventricular cavity.

The Third Ventricle.—The narrow, oblong space beneath the fornix and between the inner surfaces of the optic thalami is called the third ventricle. The *roof* of this cavity is formed by the under surface of the velum interpositum and its choroid plexus on each side: its *lateral* walls by the inner surfaces of the optic thalami; its *floor* by the parts filling the interpeduncular space. In *front* the cavity is bounded by the anterior end of the corpus callosum and by the anterior commissure; *posteriorly* it is bounded by the posterior commissure.

The cavity of the third ventricle is traversed by three commissures, called the anterior, middle, and posterior commissures.

The *anterior* commissure forms the anterior boundary of the cavity; it is a transverse band of white fibres and connects the corpora striata.

The *middle* commissure is a transverse band of gray matter which connects the optic thalami in the middle.

The *posterior* commissure forms the posterior boundary of the cavity; it is a transverse band of white fibres which connect the optic thalami behind. The third ventricle communicates by the *foramen of Monro* with the lateral ventricles above; behind and below it communicates with the fourth ventricle by the *aqueduct of Sylvius*, which is also called the *iter a tertio ad quartum ventriculum.* In the middle of its floor it communicates by an opening with the tubular process of the *infundibulum*, and through this with the interior of the pituitary body.

LECTURE XXXVIII.

THE STRUCTURE OF THE CEREBRUM.

THE cerebrum is, like all central organs of the nervous system, composed of gray and of white nerve-substance.

The gray substance of the cerebrum comprises:

1. That of the cortex.
2. That of the basal ganglia.
3 That which lines various portions of the general ventricular cavity.

1. *The Gray Matter of the Cortex.*

The gray matter which forms the cortical substance of the cerebrum covers it in a nearly equal thickness; it also covers the walls of the sulci and fissures.

This gray matter, with the exception of that in certain regions of the cerebral hemispheres, is arranged in *five distinct layers.*

These five layers are arranged as follows: The *first* or *outer* layer consists of a stratum of neuroglia which is permeated by a delicate fibrillar network, and scattered between this are small ganglion or nerve cells.

The *second* layer consists of numerous small pyramidal cells, which are closely packed together and so form a dense structure.

The *third* layer also consists of numerous pyramidal cells. but they are not closely packed as in the previous layer; they increase in size in the deeper parts. This layer is the thickest of the five.

The *fourth* layer is composed, like the second, of small, densely packed, irregular cells. Owing to the triangular or

irregular form, this layer appears granular, hence the name *granular formation*. The *fifth* layer consists of large, spindle-shaped, oblong ganglion-cells.

As before stated, there are certain locations in which the cortical substance is not arranged in five distinct layers. The exceptional locations are, according to *Meynert*, the following :

(*a*) The cortical substance of the posterior part of the occipital lobe. This consists of eight layers; the additional three layers are composed of strata of densely packed cells as in the second layer; they are interposed between the other five layers.

(*b*) The cortical substance of the hippocampus major. This consists of layers of cells identical in form and arrangement with those of the third layer. The fourth and fifth layers are absent in this region.

(*c*) The cortical substance of the walls of the fissure of Sylvius. This consists of pyramidal, spindle-shaped, and elongated cells similar to those found in the fifth layer. The *claustrum*, or collection of gray matter at the bottom of the fissure of Sylvius, is composed of such cells. The claustrum is located externally to the external capsule, between this and the white matter of the island of Reil.

(*d*) The gray matter of the olfactory bulbs, which are situated near and attached to the inferior surface of the anterior lobes on each side along the longitudinal fissure. This consists above of white matter and below of gray, the latter formed of layers of cells and medullated fibres intermingled with small cells.

The ganglion or nerve cells of the cerebral cortical substance differ in form, size, and arrangement in the various layers. They have no cell-wall, and one or more nuclei; they are either irregular, pyramidal, stellate, or spindle shape in form, and have one or more poles.

The pole of the unipolar nerve or ganglion cells is generally continuous with the axis-cylinder of a nerve-fibre

of the poles of the multipolar ganglion-cells. One ascends into the upper layer of cells and communicates with the fibres of the network of the outer layer; this is termed the *process of the apex.* Another pole, termed *the process of the centre of the base,* is directed downward toward the white substance of the cerebrum and is continuous with the axis-cylinder of a nerve-fibre. The other poles, called the *lateral processes*, form the delicate fibrillar network of the cortical gray substance.

2. *The Gray Matter of the Basal Ganglia.*

(*a*) The gray matter of the corpus striatum—viz., that of the nucleus caudatus and the nucleus lenticularis—consists of multipolar nerve-cells of different sizes; generally those of the nucleus lenticularis are larger.

The two masses of the corpus striatum are traversed by medullated nerve-fibres. Other fibres arise from the cells of the masses, and, passing out of them, pass toward the periphery of the hemispheres.

(*b*) The gray matter of the optic thalamus is composed of large, elongated, multipolar cells. It is arranged in two masses—viz., the internal and the external nucleus. The two are separated by a central septum of white nerve-substance; a thin layer of this also covers the exterior of the optic thalamus.

(*c*) The gray matter of the corpora quadrigemina consists of a peripheral layer and of a central mass; the latter constitutes part of the gray matter of the general ventricular cavity. The peripheral layer constitutes a part of the basal gray matter; it consists of small multipolar cells of a delicate fibrillar network; the outer surface is covered by a thin layer of white substance. The gray matter of the *nates*, or anterior lobes of the corpora quadrigemina, consists of two layers—the outer, or *stratum cinereum*, and the deeper, or *stratum opticum;* the latter consists of fine, longitudinal fibres and small multipolar cells embedded in

these. This stratum is separated from the central gray mass by a thin layer of white substance.

The peripheral gray matter of the testes, or posterior lobes of the corpora quadrigemina, is separated from the central gray mass by a transverse layer of white fibres.

(*d*) The gray matter of the corpora geniculata is continuous with that of the optic thalamus. It consists of multipolar nerve-cells, those of the external geniculate bodies, containing pigment granules which give them a dark color.

(*e*) The gray substance of the locus niger consists of small multipolar cells, which, owing to the presence of many pigment-granules, have a very dark color, hence the name.

3. *The Gray Matter Lining Parts of the General Ventricular Cavity of the Cerebrum.*

The gray substance of this group includes the following:

(*a*) The gray matter which covers the internal surface of the optic thalami and lines the lateral walls and floors of the third ventricle.

(*b*) That which forms the gray or middle commissure of the third ventricle.

(*c*) That which forms the gray structures enclosed in the interpeduncular space—viz., the tuber cinereum, the infundibulum, and the posterior perforated space.

(*d*) That which covers the superior surface of the tegmentum of the crura cerebri.

(*e*) The central gray mass of the corpora quadrigemina. This forms the upper and posterior wall of the aqueduct of Sylvius; it is composed of large multipolar cells which are the origin of the third and fourth pairs of cranial nerves.

The gray matter distributed to these various parts of the general ventricular cavity of the cerebrum is continuous with that lining the aqueduct of Sylvius; this is again continuous with that covering the floor of the fourth ventricle,

and this with the gray matter of the spinal cord. The gray matter in the various parts of the general ventricular cavity is composed of nerve-cells and delicate fibrillæ.

The White Nerve-Substance of the Cerebrum.

This structure consists of medullated nerve-fibres, and composes the main portion of the interior of the cerebrum.

The nerve-fibres are arranged in three groups—viz.:

1. The corona radiata.

2. The commissural fibres which pass transversely between the two hemispheres.

3. The commissural fibres which connect various parts in one hemisphere.

1. *The Corona Radiata.*—The corona radiata is a system of medullated nerve-fibres which, in the cerebral hemispheres, radiate toward their periphery, where they connect with the ganglia of the cortical substance.

The fibres of the corona radiata may be divided into (*a*) *cortico-petal* fibres, viz., those which pass to the ganglia in the cortical substance; and (*b*) *cortico-fugal* fibres, viz., those which arise from the cortical ganglia.

These fibres which radiate in the cerebral hemispheres enter and leave the cerebrum at its base, and, according to their derivation, they may be classified into:

(*a*) Those from the crusta, or inferior stratum of the crura cerebri.

(*b*) Those from the tegmentum, or superior stratum of the crura cerebri.

(*c*) Those arising from the ganglia of the locus niger, the middle layer of the crura cerebri.

(*d*) Those arising from the ganglia of the gray matter which forms the posterior part of the aqueduct of Sylvius.

The fibres from these various sources enter the hemispheres and pass upward. Some of them radiate directly to the cortical substance, ascending through the external and internal capsule between the large basal ganglia.

Others, again, enter and penetrate these ganglia—viz., the corpus striatum and optic thalamus. The fibres radiating toward the cortex above these ganglia are joined by many fibres which arise from the cells in the ganglia.

The fibres of the crusta and of the tegmentum are continuous with fibres of the pons Varolii, and these again are continuous with fibres of the various parts of the medulla oblongata, as follows:

Those longitudinal fibres of the pons which are continued upward, as the fibres of the crusta, or inferior stratum of the crura cerebri, are derived from the pyramids of the medulla oblongata.

The fibres of each pyramid of the medulla are continuous with (*a*) those of the direct pyramidal tract of the anterior column of the spinal cord on the same side, and (*b*) those of the crossed pyramidal tract of the lateral column of the cord from the opposite side.

The fibres of the various portions and fasciculi of the spinal cord ascend, forming the pyramids of the medulla; the fibres of the pyramids are continued upward to form the fibres of the crusta of the crura cerebri.

Those longitudinal fibres of the pons which are continued upward, as the fibres of the tegmentum of the crura cerebri, are derived from the *formatio reticularis* of the medulla. This is a network of longitudinal and transverse fibres contained in the substance of the medulla; they are derived from the funiculus cuneatus and the funiculus gracilis of the medulla, from the olivary body of the medulla, and from the anterior column of the spinal cord.

The fibres of the tegmentum enter and penetrate the optic thalami, and radiate, together with fibres arising from the cells of the optic thalami, toward the cortical substance of the temporo-sphenoidal and occipital lobes.

2. *The Commissural Fibres which pass transversely between the two Hemispheres.*—The fibres of this group include :

(*a*) The fibres of the corpus callosum.

(*b*) The fibres of the anterior commissure of the third ventricle.

(*c*) The fibres of the posterior commissure of the third ventricle.

(*a*) The fibres of the corpus callosum pass transversely across from one cerebral hemisphere to the other; in the hemispheres they radiate toward the cortical substance.

(*b*) The fibres of the anterior commissure pass transversely through the third ventricle in front of the anterior crura of the fornix. These fibres pass through the corpus striatum in each hemisphere, and then pass backward into the temporo-sphenoidal lobe.

(*c*) The fibres of the posterior commissure pass transversely across the posterior part of the third ventricle; some of them are derived from the tegmentum on one side. They then pass across the third ventricle, and then into the temporo-sphenoidal lobe. Others pass across the third ventricle, connecting the optic thalami on both sides.

3. *The Commissural Fibres which connect various Parts in one Hemisphere of the Cerebrum.*—The fibres of this group are:

(*a*) The fibres of the *fornix*, which connect the optic thalami with the hippocampus major.

(*b*) The *tænia semicircularis*, which separate the optic thalamus from the nucleus caudatus. These fibres pass from the anterior crura of the fornix upward toward the roof of the middle horn of the lateral ventricle.

(*c*) The *longitudinal* fibres of the *corpus callosum.*

(*d*) The *uncinate fasciculus* are bundles of fibres which connect the convolutions of the frontal with those of the temporo-sphenoidal lobes.

(*e*) The *inferior longitudinal fasciculus*—a bundle of fibres which connect the temporo-sphenoidal with the occipital lobe.

(*f*) The *fillet of the gyrus fornicatus*—a band of fibres

which begin in front in the anterior perforated space, then pass upward, winding over the anterior extremity of the corpus callosum, and then arching backward parallel with the rostrum of the corpus callosum, and continue in its convolutions; the fibres then curve downward over the posterior extremity of the corpus callosum, and pass forward in the substance of the temporo-sphenoidal lobe again to the anterior perforated space.

(*g*) The *arcuate* or *association* fibres are arching fibres which connect the central substance of the hemispheres beneath their convolutions.

LECTURE XXXIX.

THE FUNCTIONS OF THE CEREBRUM.

The cerebrum is the seat of intelligence. All psychological processes, such as thinking, feeling, remembering, judging, the perception and retention of all sensorial impressions, and all actions and functions which require thought, decision, or psychical effort, are dependent upon the normal, harmonious activity and healthy condition of the cerebrum.

The functions of the cerebrum have been studied by observation of the effects produced by irregularities and by pathological lesions of the cerebrum or of parts of it, and more definite studies have been made by experiments made on animals.

It is well known that individuals having a microcephalon—a condition characterized by a small development of the brain, and principally of the cerebrum—possess a very low degree of intelligence and are generally idiots and cretins. The same is often observed in individuals suffering from hydrocephalus. The psychical activities are more or less impaired or totally absent in individuals with injuries and pathological lesions of the cerebrum—as, for instance, degenerations, new growths, inflammations, pressure, or interference with the blood-supply. Drugs known as narcotics also suppress the psychical functions and processes.

Removal of the cerebrum of animals is followed by a total loss of all intelligence. The animal loses the power of voluntary motility; it loses the power to perceive and retain sensory impressions, and it also loses the sense of

sight, smell, hearing, touch, and of common sensation. The animal becomes a mere machine; it is incapable of retaining its equilibrium; it makes a few walking motions when pushed; it swallows when food is forced into its pharynx, and it performs all such functions and actions that are ordinarily reflex.

The many observations and experiments which have been made to determine the functions of the cerebrum have shown the following:

1. That the degree of intelligence of the individual depends upon the degree of the development of the cerebral hemispheres as compared with the other parts of the brain.

2. That the degree of intelligence depends upon the cortical gray substance of the cerebral hemispheres and upon its extent and development.

The Functions of the Various Parts of the Cerebrum.

A. *The Functions of the Gray Cortical Substance.*—The general function of the gray cortical substance of the cerebral hemispheres is to control all psychical processes, such as the production of the co-ordinated complex motions which are brought about by an effort of the will and with a certain purpose—as, for instance, the motions concerned in the act of speaking, by which ideas are expressed in words; again, processes such as the understanding of sounds and language, the recognition of sights, etc.

It was formerly believed that these functions were equally possessed by all parts of the cortical gray substance of the cerebral hemispheres, and that if any part was destroyed the remaining parts would take up its function, so that no disturbance of any of the functions was produced. Later experiments have shown, however, that this theory is erroneous, and that the seats for the various functions are localized in various parts of the cortical gray substance.

Many experiments and observations have been made to

localize the various functions and to map out the areas on the exterior of the cerebral hemispheres. In animals this was done by the gradual and methodical removal of parts of the cortical gray substance and observing the effects resulting from this. In man, observation of the effects produced by lesions in parts of the cerebral cortical gray substance aided in localizing the exact seat of many functions. The method most employed is the stimulation of the various regions of the cortical gray substance by the application of weak electric currents and observing the effects so produced.

Scientists who made this a special subject for their studies and experiments have thus succeeded in localizing many of the functions—a fact which is most valuable for the localization of injuries and pathological lesions of the cerebral hemispheres.

The areas which are the seat of the various functions of the cortical gray substance have thus been located and mapped out on the surface of the cerebral hemispheres as follows:

I. The *cortical* or *psycho-motorial* centres are located in an area which includes the posterior part of the frontal lobes and the middle and superior regions of the parietal lobes. The psycho-motorial centres are those which govern the co-ordinated contractions of the muscles employed in the production of voluntary motion.

These cortical motor centres for the various groups of muscles are located in the following circumscribed regions of this area:

1. The centre for the *extensors of the arms and hands* is located in the posterior part of the superior and middle frontal convolutions, near the margin of the pre-central sulcus.

2. The centres for the *rotation of the hands* and for the *flexion of the forearm* are located just above the centres for the elevation and depression of the angles of the mouth,

viz., in the mid-portion of the ascending frontal convolutions.

3. The centres for the movements of the *wrists* and *fingers* are located in the ascending parietal convolutions.

4. The centres for the movements of the *hands* and *feet* are located in the superior parietal convolutions, near the posterior central sulcus.

5. The centres for the complex movements of the *arms* and *legs*—as, for instance, the motions by which swimming is effected—are located in the upper portion of the ascending frontal convolutions, near the longitudinal fissure.

6. The centres for the movements of the *eyes* are located in the middle frontal convolutions, near the margin of the pre-central sulcus.

7. The centres for the *elevation* and *depression of the angles of the mouth* are located in the middle portion of the ascending frontal lobes.

8. The centres for the *retraction of the angles of the mouth* are located in the lower portion of the ascending frontal lobes or convolutions, just above the ascending limb of the fissure of Sylvius.

9. The centres for the movements of the *lips* and *tongue* are located in the inferior frontal and in the lower part of the ascending frontal convolutions, near the margin of the pre-central sulcus.

10. The centre for the motions of *speech* is located in the lower part of the ascending frontal convolution and in the island of Reil, around the fissure of Sylvius and the pre-central sulcus.

It has been observed that a condition known as *aphasia*, which is characterized by the inability te express ideas in language, is produced by disease or lesions of this region on the *left* cerebral hemisphere, and it is therefore believed that the speech centre is located in this region only. The lesion which produces aphasia does not produce paralysis of the muscles of speech, but it produces a disturbance of

the co-ordinated harmonious motions of these muscles that are essential for articulate speech.

Irritation of the various motor regions of the cortical substance of one cerebral hemisphere produces contractions of the described muscle groups on the opposite side of the body. This shows that the cortical substance of these various regions contains motor centres for these respective muscle groups. In the cortical substance of these regions are large pyramidal ganglion cells, the descending poles of which are continuous with the axis-cylinder of the motor nerve-fibres of the corona radiata. That these ganglia are the centres for these nerve-fibres is shown by the fact that these fibres degenerate and lose their irritability when the centres are destroyed or removed. Irritation of the fibres of the corona radiata beneath the cortical motor regions produces the same motions as direct irritation of the cortical substance of these regions.

Strong irritation of the cortical substance of the motor region produces convulsive muscular contractions; this is often observed in pathological lesions of the cortical motor areas which cause irritation; the convulsive muscular contractions so produced are known as *cortical* or *Jacksonian epilepsy*.

Irritation of the cortical motor regions by the application of certain chemicals, such as the ingredients of urine —viz., keratin, kreatinin, urea, etc.—also produces repeated clonic and tonic convulsive muscular contractions followed by coma or total loss of the irritability of these regions.

It is believed that eclampsia and coma of uræmia are so produced by the retention of such urinary ingredients in the system.

Irritability of the cortical motor regions is totally suppressed in the condition of deep narcosis produced by the administration of alcohol, ether, chloroform, morphine, etc. These drugs, when taken in small doses, at first increase the irritability of the motorial regions. In the con-

dition known as *apnœa* and *asphyxia* the irritability of the cortical motorial regions is also suppressed.

Slight inflammatory conditions, slight hyperæmia, and a small loss of blood increase, while a large loss of blood and the application of cold decrease, the irritability of the cortical motor regions.

Extirpation or destruction of the cortical motor centres produces peculiar motorial disturbances of the respective muscle groups, in that the motions are powerless and not co-ordinated and regular. The more complicated motions which require a certain psychical effort can no longer be performed.

The motor fibres arising from the cortical motor centres pass downward in the corona radiata through the internal capsule; they then pass to the crura cerebri, and are contained in the inferior stratum or crusta of the latter.

Extirpation of the cortical centres from which these nerve-fibres arise is soon followed by their degeneration.

II. Psycho-sensorial cortical centres are located in an area which includes (*a*) the area of the cortical psycho-motorial centres, and (*b*) the superior temporo-sphenoidal convolution, the lower posterior part of the ascending parietal convolution, the supramarginal and angular portion of the inferior parietal convolution, and the middle occipital convolution.

The psycho-sensorial centres are those by which we perceive the impressions of sensible things, and by which we recognize the character of such impressions—as, for instance, the impression produced by the firing of cannon, the form and nature of the things we touch, the nature of odors, sights, and sounds.

The centres by which we perceive the various impressions of sensible things are located in certain distinct, circumscribed regions of the above-described area of the psycho-sensorial centres. The location of these various regions has been mapped out as follows:

1. The cortical or psycho-sensorial centres for the *sense of touch* and *common sensations* of the various parts of the body, are located in the regions of the cortical substance which are the seat of the psycho-motorial centres for the muscles of those respective parts of the body.

It has been observed that the motorial disturbances of a certain muscle-group, produced by the removal of the respective psycho motorial centres, is accompanied by disturbances of the sense of touch and of common sensation in the region of that muscle-group. It is therefore believed that the psycho motorial regions for certain parts of the body are also the seat of the centres for the sense of touch and common sensation of the same part of the body.

2. The cortical or psycho-sensorial centre for the *sense of sight* is located principally in the middle occipital convolution, but the visual sphere also extends upward along the cortex of the angular portion and along that of the supramarginal portion of the inferior parietal convolution.

Total destruction of these visual spheres produces total blindness ; destruction on one cerebral hemisphere produces blindness on the opposite side. The visual power does not return when the visual sphere in one or both hemispheres is totally destroyed.

Destruction of certain parts of the visual sphere causes a decrease of the visual power and a loss of the power to recognize the various visual impressions. If, in a dog, a certain portion of the visual sphere is destroyed, the animal becomes blind, but gradually regains a certain degree of visual power, but is unable to recognize the objects which are brought before it. It has been observed that this condition, when it is produced in an animal by experimental excision of certain parts of the visual sphere, gradually improves, so that the animal again learns to see and recognize various objects. This is believed to be due to the fact that the other portions of the visual sphere gradually assume the functions of the removed portion.

3. The cortico- or psycho-sensorial centre for the *sense of hearing* is located in the superior temporo-sphenoidal convolution, near the margin of the horizontal limb of the fissure of Sylvius. Destruction of the cortical substance in this region produces deafness on the opposite side. Destruction of certain regions of this sphere causes a temporary loss of the power to recognize the various acoustic impressions.

4. The cortical or psycho-sensorial centres for *smell* and *taste* are, according to *Munk*, located in the gyrus hippocampi. Destruction of the cortical substance of this region on both cerebral hemispheres causes a loss of smell and taste. The exact circumscribed area of these centres is not determined as yet.

5. The presence of certain cortical *thermal centres* has been detected by *Eulenberg* and *Landois*. They have been located in certain psycho-motorial regions of the frontal and parietal lobes. Experiments and observations show that in these regions are located centres which influence the temperature of certain regions.

The *sensory nerves* which communicate and are connected with these various cortical or psycho-sensorial centres radiate in the corona radiata and pass along the internal capsule. Many of them are continuous with those of the tegmentum or upper stratum of the crura cerebri.

III. The cortical centres which preside over the higher *psychical* functions and processes—such as thinking, judging, remembering, deciding, etc.—have their seat in the antero-lateral regions of the frontal lobes and in the lower part of the temporo-occipital regions of the cerebral hemispheres. Numerous clinical observations tend to show that these regions are the seat of such higher psychical functions. It has been observed that in weak-minded elderly people, or in those of a low grade of intelligence, these regions are atrophied. Weakness of mind, loss of

intelligence, and even idiocy, are often caused by lesions of the frontal lobes.

B. *The Functions of the Basal Ganglia and of other Parts of the Cerebrum.*—1. The function of the *corpus striatum* is believed to be that of a motor ganglion which is interposed in the course of the fibres arising from the cortical psycho-motorial fibres. This theory is based upon clinical observations and on physiological experiments. It has been observed that removal or pathological lesions of the corpus striatum cause hemiplegia—viz., the inability to perform voluntary muscular contraction on the opposite side of the body.

The decussation of the fibres arising from the psycho-motorial or cortical centres takes place beneath the corpus striatum.

2. The function of the *optic thalamus* is believed to be that of a sensory centre interposed in the course of the fibres connected with the cortical psycho-sensorial centres. This is only a theory based upon clinical observations and the results obtained by physiological experiments.

Removal and certain pathological lesions of one cerebral hemisphere are followed by loss of sensation on the opposite side of the body. The sensorial fibres passing through the optic thalami also decussate beneath these.

3. The functions of the *corpora quadrigemina* are best explained by the description of the effects produced by their removal or by certain pathological lesions. Removal of the corpora quadrigemina produces total blindness of both eyes. Removal of one produces blindness of the eye on the opposite side. Removal of the corpora quadrigemina produces a dilatation of the iris and destroys the coordination of the movements of the eyes.

From this description the functions of the corpora quadrigemina may be summed up as follows:

(*a*) They are subcortical centres for the sense of sight.

(*b*) They contain centres which govern the movements of the iris.

(*c*) They govern the co-ordinated motions of the eyes.

4. The functions of the *corpora geniculata* are not exactly known. Their removal is followed by disturbances similar to those caused by the removal of the corpora quadrigemina.

5. The functions of the *crura cerebri* are largely those of conducting organs : the fibres of the crusta conduct motor impulses; those of the tegmentum, sensory impulses.

The middle gray substance of the crura, called the locus niger, is the subcortical centre for certain complex movements of the eyes. From these centres arise the third cranial nerves, through which the motorial impressions from these centres are conducted to muscles of the eyes.

6. The functions of the *pituitary body* and the *pineal gland* are unknown; no apparent effect is produced by their removal.

7. The functions of the *corpus callosum*, and of the *commissures* in the *third ventricle*, are to connect the various parts of the cerebral hemisphere.

8. The function of the *medullary substance* of the cerebral hemisphere is to conduct the various impressions to, or from, or between the various structures of the cerebral hemisphere.

9. The function of the fornix is probably that of a conducting organ.

10. The functions of the *gray nerve-structures* which fill the *interpeduncular space*, the *anterior perforated spaces*, and which line the various parts of the *ventricular cavity* of the cerebrum, cannot be separately described, but they are probably connected with the functions of those structures of gray nerve-substance with which they are in contact.

From this description of the functions of the various parts of the cerebrum, it will be seen that it is a complex

structure of many organs, each possessed of distinct functions. Destruction of certain parts of the cerebrum is followed by certain characteristic mental or physical disturbances.

LECTURE XL.

THE CEREBELLUM.

1. *Anatomy and Structure.*

THE cerebellum is that portion of the brain which occupies the posterior fossæ of the cranium. It is oval in form and measures about $3\frac{1}{2}$ to 4 inches in its lateral and $2\frac{1}{2}$ inches in its antero-posterior diameter; it is about 2 inches thick in the centre, and gradually becomes thinner toward its periphery or margin. The weight of the cerebellum of man is about $5\frac{1}{4}$ ounces; the proportion of the cerebellum and the cerebrum is about 1 to $8\frac{3}{4}$.

The cerebellum is divided into an upper and a lower part by a fissure which passes around the margin of the cerebellum; this is called the *great horizontal fissure.* From this several fissures or sulci pass in a transverse direction over the upper and lower surfaces of the cerebrum, dividing it into several lobes.

The *upper* surface of the cerebellum is higher in the middle than at its edges; it is directed toward the under surface of the occipital lobes of the cerebrum, and is separated from them by the *tentorium cerebelli.* This surface is divided into two lateral hemispheres. These are completely separated in front by a concavity which is called the *incisura cerebelli anterior;* this surrounds the posterior portion of the corpora quadrigemina. Behind, the hemispheres are separated by a similar concavity, which is called the *incisura cerebelli posterior.* In the middle the hemisphères are united by an elevated mass which is called the *median* lobe, or the *superior vermiform process.*

The upper surface of each cerebellar hemisphere is divided by a transverse curved fissure into two lobes, called the anterior or square lobe and the posterior or semilunar lobe. The *anterior* or *square lobe* is the larger; it is the portion anterior to the fissure; its inner border extends backward to the posterior end of the vermiform process.

The *posterior* or *semilunar lobe* is narrower than the former; it is the portion posterior to the fissure, and is limited behind and below by the great horizontal fissure.

The *lower* surface of the cerebellum is divided by a wide longitudinal furrow along the median line into two lateral hemispheres. This furrow covers the back part of the medulla. The under surface of each cerebellar hemisphere rests in the posterior fossæ of the cranium on its side

This surface is divided by several fissures into five lobes, which, beginning at the front, are named as follows: 1, the flocculus; 2, the amygdala, or tonsil; 3, the digastric lobe; 4, the slender lobe; 5, the posterior inferior lobe.

1. The *flocculus* is that portion of the under surface which is situated anteriorly and beneath the great transverse commissure or middle peduncle of the cerebellum.

2. The *amygdala*, or *tonsil*, is situated behind and internally to the flocculus; its inner border forms part of the margin of the valley or middle furrow.

3. The *digastric lobe* is situated behind and externally to the amygdala, and separated from it by a curved fissure.

4. The *slender lobe* is situated behind the digastric lobe, and is separated from it by another curved transverse fissure.

5. The *inferior posterior lobe* is situated posteriorly to the former lobe, and extends backward to the great horizontal fissure which separates it from the superior posterior or semilunar lobe of the upper surface of the hemisphere.

The longitudinal median furrow which divides the under surface of the cerebellum into the two hemispheres

is called the *valley;* projecting from the floor of it is an elongated prominence which is called the *inferior vermiform process*, and consists of four parts, which, beginning at the rear, are as follows: the commissura brevis, the pyramid, the uvula, and the nodule.

The *commissura brevis*, or *tuber valvulæ*, is a small, transverse band which unites the inferior, posterior, and the slender lobes of the two hemispheres.

The *pyramid* is situated in front of the commissura brevis, between the two hemispheres.

The *uvula* is the portion which is placed between the amygdalæ or tonsils of the two hemispheres.

The *nodule* is the anterior cone-like termination of the inferior vermiform process; the nodule projects into the fourth ventricle. From each side a wide band passes outward to the side of the flocculus on each side; this is called the *posterior medullary velum*, or the *commissure of the flocculi*.

The cerebellum consists of a layer of gray nerve-substance externally and white nerve-substance internally. The external gray covering is called the cortical substance; the internal white matter is called the medullary substance; in the midst of this is a mass of gray substance which is called the *corpus dentatum*.

The Cortical Gray Matter of the Cerebellum.

The surface of the cerebellum is traversed by numerous transverse arched furrows or sulci; these give to the surface a transversely striated and foliated appearance. The purpose of these sulci is the same as that of the sulci of the cerebrum—viz., to increase the surface without an increase of the cerebellar surface itself.

The cortical gray matter of the cerebellum consists of laminæ which extend outward from the surface of the medullary substance, and which are separated by the sulci

on the surface of the cortex. If examined microscopically it will be seen that it consists of two distinct layers.

The *outer* layer is grayish in color; it consists of neuroglia, of delicate connective-tissue fibres, of small granular cells, and, lastly, of nerve-fibrillæ which are continuous with poles of certain cells in the depth of this layer, and pass outward at right angles. The cells from which these fibres arise are called the *corpuscles of Purkinje;* they are the characteristic cells of the cerebellum. They are oblong in shape and give off from their upper border processes which ascend in the upper layer. From their lower border these cells give off poles, or elongated processes, which pass inward through the inner layer and are continuous with the axis-cylinder of the medullated nerve-fibres of the medullary substance.

The *inner* layer of the cortex is of a reddish color; it is composed of numerous small, granular, nucleated cells; they are stellate in form and give off delicate processes which form a fine reticulum between the cells; the whole is embedded in a matrix of gelatinous material.

The Medullary Substance of the Cerebellum.

The medulla of the cerebellum presents, on a transverse section of the organ, the shape of a tree consisting of a stem and many rami; this peculiar arrangement is called the *arbor vitœ.*

The medullary substance consists of medullated nerve-fibres, which, according to their arrangement, are divided into (1) the commissural fibres, (2) the arcuate or association fibres, (3) the peduncular fibres.

1. The *commissural* fibres are those which pass transversely through the anterior and posterior part of the vermiform process connecting the two hemispheres.

2. The *arcuate* or *association* fibres are those which pass around the bottom of the sulci and connect the laminæ of the cortical substance of each hemisphere.

3. The *peduncular* fibres are those which are continued into the peduncles of the cerebellum.

The Peduncles of the Cerebellum.

The cerebellum is connected with the other parts of the brain by bands of nerve-fibres which are called its peduncles—three on each side, called the superior, middle, and inferior peduncles.

The *superior peduncles* are two round bands, one on each side, which connect the cerebellum with the corpora quadrigemina of the cerebrum in front.

The *superior peduncle*, or *processus e cerebello ad testes,* consists of nerve-fibres which arise from the optic thalamus on its side; these pass forward to the upper surface of the crura cerebri, and finally emerge as a round band from beneath the posterior border of the testes of the corpora quadrigemina. As the two peduncles emerge they pass backward and diverge to enter the hemispheres of the cerebellum; in these, most of the fibres of each peduncle enter the corpus dentatum, and some of these pass to the cortical substance of the under portion of the cerebellum.

Some of the fibres of the superior peduncles decussate beneath the corpora quadrigemina, so that each peduncle as it emerges from the testes contains fibres from the optic thalami on both sides. As the superior peduncles pass backward and diverge they form the upper part of the lateral boundary of the fourth ventricle. Above, the superior peduncles are connected by a thin transverse lamella of white substance which is called the *valve of Vieussens* and forms a part of the roof of the fourth ventricle; it is connected in front with the posterior border of the testes, and behind with the anterior end of the vermiform process.

The *middle peduncles*, or *crura of the cerebellum*, also called the *processus ad pontem*, are two thick bands of nerve-fibres which arise from the cells of the cortical gray substance of the cerebellar hemispheres, and then curve forward to the pons Varolii, forming its deep transverse fibres.

The *inferior peduncles* connect the cerebellum with the medulla oblongata.

The inferior peduncle, or *processus ad medullam* on each side, consists of continuous fibres of the restiform body on that side of the medulla. As the peduncles pass upward they diverge and form the inferior part of the lateral boundaries of the fourth ventricle. The fibres of the inferior peduncles enter the cerebellar hemispheres and pass to the cortical gray substance in their upper part.

The Central Gray Mass or Ganglion of the Cerebellum.

The *corpus dentatum*, or ganglion of the cerebellum, is located near the centre of the medullary substance; it consists of a capsule of gray substance which has a serrated surface; from the interior of the capsule nerve-fibres emerge which pass outward in the superior peduncles of the cerebellum.

Situated at the anterior end or point of the vermiform process are two microscopical masses of gray substance; they are called the *roof nuclei of Stilling* and project into the roof of the fourth ventricle.

The Functions of the Cerebellum.

The cerebellum is the organ which governs the harmony and co-ordination of the voluntary movements; it is also the organ for the sense of body equilibrium.

Removal of parts or the whole of the cerebellum is not followed by a loss of sensation or any of the special senses, nor by a paralysis of any muscles; the cerebellum is therefore not an organ of motion or of sensation.

When the cerebellum of an animal is removed it is no longer capable of maintaining the equilibrium of its body; its motions become weakened and disorderly, the animal assumes a staggering, unsteady gait, it often moves backward instead of forward, and it has a tendency to fall backward.

Removal of one lateral half is followed by motor disturbances on one side of the body. These disturbances have the character of *forced movements;* the animal makes peculiar jerky, convulsive motions, and has a tendency to fall to one side and to roll continuously sideways, always rolling toward the side from which the cerebellar half is removed.

These experiments and observations, and the anatomical relations of the cerebellum to the other parts of the brain, tend to show that the efferent fibres arising from the cells of gray substance of the cerebellum conduct impulses which influence the motor impulses which arise from the other organs of the brain.

THE PONS VAROLII.

Its Anatomy and Structure.

The pons is that portion of the brain which connects its various parts; it is situated below the crura cerebri, in front of the cerebellum, and above the medulla oblongata.

The pons consists of an anterior and a posterior part.

The *anterior* part is composed of transverse and longitudinal fibres, and, interposed between these, smaller masses of gray matter.

The *anterior* surface consists of a superficial layer of transverse fibres, which laterally are continued outward and backward and form the middle peduncles of the cerebellum. Above this superficial layer there is a mass of longitudinal fibres; these are continuous with the fibres of the pyramids of the medulla, and are continued upward as the fibres of the crusta or superficial layer of the crura cerebri. Above this layer of longitudinal fibres is a third, the deep transverse layer; its fibres pass out laterally and form, with the superficial transverse fibres, the middle peduncles of the cerebellum.

In the layer of the deep transverse fibres are numerous collections of nerve-cells which are connected with some of

the fibres of this layer. There is also located, near the lower end, a collection of gray matter which is called the *superior olivary nucleus;* it is covered with transverse fibres which are called the *trapezium;* these fibres are probably connected with the cells of the olivary nucleus.

The anterior surface of the pons presents a striated appearance, which is produced by the superficial transverse fibres; anteriorly this surface is marked by a well-defined border from which the crura cerebri emerge.

The *upper* portion of the pons is composed of the continuation of the formatio reticularis of the medulla oblongata.

The *posterior* surface of the pons forms part of the floor of the fourth ventricle. The structure of this surface contains several collections of nerve-cells, which are the deep origin of some of the cranial nerves.

These nuclei are arranged in pairs—one pair from which the sensory roots of the fifth nerves arise; a second pair from which the motor roots of the same nerves arise; a third pair are the deep origin of the sixth pair of cranial nerves; a fourth pair from which the facial or seventh nerves arise; and a fifth pair from which the eighth cranial or auditory nerves arise. This last pair is situated at the junction of the pons with the medulla.

The Functions of the Pons Varolii.

The pons is an organ of conduction. Through its various fibres impressions are conducted to and from the various parts of the brain and the medulla oblongata and spinal cord. Section or destruction of parts of the pons produces sensory and motorial disturbances—viz., anæsthesia and paralysis.

The function of the pons as a nerve-centre is not known. The physiology of the various nuclei on the posterior surface of the pons I will consider later in connection with the physiology of the cranial nerves.

LECTURE XLI.

THE MEDULLA OBLONGATA.

Its Anatomy and Structure.

The medulla oblongata is that portion of the cerebrospinal axis which connects the spinal cord with the brain.

The medulla is pyramidal in form, and directed with its base forward and upward and with its apex backward and downward. Its anterior surface rests on the basilar process of the occipital bone, and its posterior surface is covered by the valley or groove which separates the two cerebral hemispheres; the anterior part of the posterior surface of the medulla forms a part of the floor of the fourth ventricle. The medulla is about 1 inch long, three-quarters of an inch wide, and half an inch thick at its base, and thinner and round toward the apex.

The medulla oblongata is divided into symmetrical lateral halves by an anterior and a posterior median fissure which runs along the middle line of its anterior and posterior surface, and which is continuous below with the corresponding fissure of the spinal cord.

The *anterior median* fissure is interrupted below by the decussation of the fibres of the pyramids.

The *posterior median* fissure expands at about the middle of the posterior surface, the space between its sides forming the posterior part of the floor of the fourth ventricle.

Each lateral half of the medulla is divided by shallow longitudinal furrows, from which some of the cranial nerves arise, into several columns which are continuous with the columns of the spinal cord.

That portion which is situated between the anterior median fissure and the furrow from which the several filaments of the hypoglossal nerve arise is called the *anterior pyramid;* it is continuous with the anterior column of the cord. That portion which is situated between the furrow from which the filaments of the hypoglossal nerve arise, and that from which the fibres of the glosso-pharyngeal, the pneumogastric, and the spinal accessory nerves arise, is continuous with the lateral column of the cord. In the lower part of the medulla this portion is called the *lateral tract;* in the upper part of the medulla an oval mass, called the *olivary body*, protrudes between the anterior pyramid and the lateral tract.

That portion of the medulla which is continuous with the posterior column of the cord is situated between the furrow from which the fibres of the glosso-pharyngeal, the pneumogastric, and the spinal accessory nerves arise, and the posterior median fissure. This segment of the medulla is divided by several shallow longitudinal grooves into minor columns. In the lower part of the medulla these are called, from the posterior median fissure outward, the *funiculus gracilis*, the *funiculus cuneatus*, and the *funiculus of Rolando.* In the upper portion of the medulla the funiculus cuneatus and the funiculus of Rolando join and form the *restiform body.*

The *pyramid* or *anterior column* on the surface of the medulla, on each side of the anterior median fissure, consists of two bundles of longitudinal fibres. The *outer* portion of these fibres is continuous with the fibres from the *direct pyramidal tract* of the *anterior column* of the spinal cord on the *same* side; the *inner* portion of these fibres is continuous with the fibres which are seen to decussate across the anterior median fissure in its lower part. These fibres are derived from the *crossed pyramidal tract* of the *lateral column* on the *other* side of the cord.

The fibres of the pyramids ascend as the longitudinal

fibres of the pons Varolii, and they are continued upward and forward as the fibres of the superficial portion or the crusta of the crura cerebri; they finally enter the cerebral hemispheres, some passing through the internal capsule directly to the cortical substance, and some through the corpus striatum. Above, the anterior pyramid is separated from the olivary body by a furrow.

The *lateral tract* of the medulla consists of fibres arranged in three sets; they are continuous with the fibres of the several fasciculi of the lateral column of the spinal cord.

The three sets of fibres of the lateral tract of the medulla are:

1. The *lateral cerebellar* set are continuous with the fibres of the cerebellar column of the lateral column of the cord on the same side; the fibres ascend and pass backward to join the fibres of the restiform body of the posterior segment of the medulla; in the restiform body these fibres pass backward, forming the inferior peduncle of the cerebellum on one side.

2. The *crossed pyramidal* set. Its fibres are continuous with those of the crossed pyramidal fasciculus of the cord below on the same side. In the medulla these fibres ascend for a short distance, then pass transversely behind the pyramid on the same side, and, decussating across the median fissure, join the fibres of the pyramid on the opposite side.

3. This set consists of the fibres of the *anterior radicular zone* and the *mixed lateral column* of the *lateral column of the cord* on the same side. In the medulla these fibres ascend in the *formatio reticularis*, to be described later.

The *posterior segment* or column of the *medulla* consists, in the lower part, of several minor columns.

The *funiculus gracilis* is that column of the posterior segment of the medulla which is placed beside the posterior median fissure; its fibres are continued from those of the column of Goll or the posterior median column of the cord.

The *funiculus cuneatus* is that column of the posterior segment which is placed externally to the funiculus gracilis. The fibres of the funiculus cuneatus are continuous with the fibres of the funiculus cuneatus of the posterior column of the cord.

The *funiculus of Rolando* is that column which is located externally to the funiculus cuneatus.

The funiculus of Rolando is an elongated prominence or elevation in the lower part of the posterior segment of the medulla, produced by the enlargement of the head of the posterior horn of gray matter in this part of the medulla. This enlargement is covered with a layer of longitudinal fibres which are continuous from below with some of the fibres of the funiculus cuneatus of the spinal cord.

The fibres of the funiculus of Rolando, and those of the funiculus gracilis of the posterior segment of the medulla, join together in the upper part of this segment, forming a column which is called the *restiform body;* in this they pass outward and upward to form the inferior peduncle of the cerebellum on its side. Some fibres of the funiculus cuneatus probably terminate in a collection of gray matter which is called the *nucleus cuneatus;* this is located in the upper portion of the substance of the funiculus cuneatus, causing a rounded prominence on its surface at that point.

The fibres of the *funiculus gracilis* do not pass up to the restiform body, but terminate in a mass of gray substance which is placed in the substance of the funiculus in its upper portion. This gray mass is called the *nucleus gracilis;* it produces a round prominence on the outer surface of this funiculus.

The *olivary body* is an oval-shaped body which consists externally of white matter, and internally of gray substance in the form of a dentated capsule: this capsule is called the *corpus dentatum of the medulla.* The olivary body is situated on the anterior aspect of the upper part of the medulla, between the anterior pyramid and the resti-

form body. It is placed somewhat behind the pyramid, and separated from it by a groove from which the fibres of the hypoglossal nerve arise; from the restiform bodies it is separated by a groove from which the pneumogastric, hypoglossal, and the spinal accessory nerves arise.

From the anterior median fissure in the upper part of the medulla are seen to emerge a set of fibres which arch over the pyramid and over the under part of the olivary body on each side, and then enter the restiform body; these are called the *superficial arcuate* or *arciform fibres.*

The Structure of the Medulla.

The medulla oblongata consists of *white matter externally* and *gray matter internally.* If a transverse section of the medulla is made, it will be seen that the surface of this section is divided into three wedge-shaped areas or segments by the various cranial nerves, which from their nuclei pass horizontally outward to emerge from the shallow grooves, on the outer surface of the medulla, which divide it into the several columns above mentioned. These three areas are called the anterior, posterior, and lateral area. The *anterior* area is the portion between the median fissure and the hypoglossal nerve, which, from its nucleus in the rear of the medulla, passes horizontally outward and forward through the substance of the medulla, and which finally emerges from the shallow groove on the surface of the medulla which separates the anterior pyramid in front from the lateral segment. The *lateral* area is the portion between the hypoglossal nerve as it passes horizontally forward and outward from its nucleus, and the pneumogastric nerve, which from its nucleus passes horizontally outward to emerge from the furrow which, on the surface of the medulla, separates the lateral segment from the posterior segment.

The *posterior* area is the portion posterior to the horizontally passing outward pneumogastric nerve; this portion

is separated from the same area on the other side of the medulla by the posterior median fissure on the outer surface of the medulla; this area corresponds to the portion which, by several shallow longitudinal fissures, is divided into the several minor columns above mentioned.

The peripheral portion of these three areas is composed of the fibres which form the various columns into which the surface of the medulla is divided. The inner portion of these areas is composed of a reticulated structure of nerve-fibres which is called the *formatio reticularis;* this structure consists of longitudinal and transverse fibres.

The *longitudinal* fibres are:

1. The fibres of the fundamental fasciculus of the anterior column of the cord.

2. The fibres from the mixed lateral column and from the anterior radicular zone of the lateral column of the cord.

3. Fibres arising from the capsule or interior of the corpus dentatum of the olivary body of the medulla.

4. The fibres from the funiculus cuneatus and from the funiculus gracilis which pass to their respective nuclei.

The *transverse* fibres of the formatio reticularis are the deep arcuate or arciform fibres. These fibres are very abundant. Some of them join the superficial arciform; some pass to the *raphe* in the anterior median fissure, which is formed by the meeting of the superficial arciform fibres from both sides of the medulla. These fibres arise from ganglion cells in the depth of the anterior median fissure; from these cells also arise some of the deep arciform fibres; some of these pass into the restiform bodies. Most of the fibres of the formatio reticularis are continued upward and forward in the upper layer or tegmentum of the crura cerebri; in the cerebral hemispheres the fibres of the tegmentum pass up to the optic thalami.

The fibres of the formatio reticularis and those of the columns constitute the white substance of the medulla.

The Gray Substance of the Medulla.

In the lower part of the medulla the gray substance is continuous with that of the spinal cord. On transverse section of the lower part of the medulla it presents the same arrangement as in the cord—namely, each lateral half of the medulla contains a crescentic mass directed with its concavity outward, and having an anterior horn which passes outward, and a posterior horn which passes backward into the substance of the medulla.

In the upper part of the medulla the gray matter is more abundant and not arranged with such regularity as in the lower part. At the point on the posterior surface of the medulla where the funiculi graciles and the restiform bodies diverge as they pass upward to form the posterior lateral boundary of the fourth ventricle, the gray matter is exposed. The point where the posterior median fissure separates is termed the *calamus scriptorius.* At this the central canal of the gray matter expands and the gray matter spreads, forming the covering of the floor of the fourth ventricle; in it are seen prominences which are caused by a collection of cells which are the nuclei for several of the cranial nerves.

The gray mass of the horns of the crescentic masses is separated into several masses or nuclei by the fibres of the white substance of the medulla; in these regions these masses are pushed outward toward the columns on the surface of the medulla and toward the floor of the fourth ventricle.

The head of the anterior horn is separated from the main mass by fibres of the crossed pyramidal tract of the cord. As they decussate in the medulla this mass is pushed outward toward the lateral tract, and constitutes the *lateral nucleus* which is situated beneath the surface of this tract.

The other portion of the anterior horn is also separated into several masses by the fibres of the formatio reticularis; one of these masses is pushed toward the floor of the fourth

ventricle, producing in it an elevation; this mass is known as the *nucleus teres*. From a group of nerve cells arise the fibres of the hypoglossal nerve.

The head of the posterior horn is separated from the main mass; it enlarges and is pushed outward, forming a separate mass which is situated near the surface of the lateral tract, causing the protrusion of the funiculus of Rolando on the outer surface of the medulla posteriorly.

The main portion of the posterior horn is divided into two separate masses which are called the *nucleus gracilis* and the *nucleus cuneatus*; these are situated beneath the surface of the funiculus gracilis and the funiculus cuneatus. Another separate mass from the posterior horn is pushed toward the floor of the fourth ventricle, producing in it an elevation which is called the *ala cinerea*. This is situated externally to the elevation produced by the nucleus teres; from it arise the roots of the pneumogastric, the glosso-pharyngeal, and the accessory branch of the spinal accessory nerve. Externally to the ala cinerea is located a mass of ganglion cells from which the main portion of the auditory nerve arises. In the substance of the medulla there is another separate mass—viz., the *corpus dentatum* of the olivary body.

The Functions of the Medulla Oblongata.

The medulla conducts impulses from the spinal cord to the brain, and *vice versa*, and also impulses which originate in the various centres in the medulla. The medulla also transfers impulses. But it is not only an organ for the conduction and transference of impulses; it is also the seat of the centres of many important functions, such as respiration, etc. The brain and portions of the spinal cord may be injured or removed and life may still continue for some time. But injury to the medulla, especially in its middle part, often causes instantaneous death, owing to the destruction of the respiratory and cardiac centres.

The activity of the various nerve-centres in the medulla may be *automatic* or *reflex*. The normal activity of these centres depends upon the proper exchange of the gases of the blood.

The automatic centres in the medulla are:

1. The centre of respiration.
2. The cardio-inhibitory centre.
3. The cardio-accelerating centre.
4. The vasomotor centre.
5. The vasodilator centre.
6. The sweat centre.

The *centre of respiration* is located in the gray matter of the floor of the fourth ventricle, between the origin of the pneumogastric and spinal accessory nerves. The centrum is double-sided; when divided longitudinally the respiratory movements will continue symmetrically on both sides, but if one lateral half of the centre is destroyed the respiratory movements will cease on that side of the body. The centre of respiration consists, on each side, of two parts—one which influences the inspiratory, and one the expiratory movements. The respiratory centre is automatic and by its rhythmical activity presides over the regularity and rhythm of the respiratory motions. The activity of the centre may also be influenced by reflex impressions conveyed to it through centripetal nerves. It has been observed that the pulmonary branches of the pneumogastric conduct accelerating impressions to the centre of respiration. Section of these causes a decrease of the respiratory movements. Nerves conducting accelerating impressions to the centre of respiration are also contained in the nerves of the skin and in the sensory nerves of the eye and ear.

Inhibitory impulses are conducted to the centre in fibres of the superior and inferior laryngeal branches.

The respiratory motions are also, to a certain extent, under the control of the will.

The irritability and activity of the respiratory centre depend upon the quantity of O and CO_2 in the blood. An excess of O and diminution of CO_2 decreases or totally interrupts the irritability and activity of the centre, producing the condition known as *apnœa.*

An increase of the CO_2 and decrease of O in the blood produces *dyspnœa,* characterized by rapid and labored respiratory motions and deep respirations.

Experiments have shown that in the cerebral hemispheres, and also in the spinal cord, there are situated respiratory centres, which, however, are subordinate to, and controlled by, the centre in the medulla.

The *cardio-inhibitory centre* is located near the restiform body; it is an automatic centre. Its irritability and its activity are influenced, like those of the respiratory centre, by the quantity of O and CO_2 in the blood.

The activity of this centre may also be influenced by reflex impressions received through centripetal nerves. The centre may be irritated by irritation of the vagus and of the cervical and abdominal sympathetic nerves. For example, a blow against the abdomen may cause death by irritation of the sensory nerves of the abdominal viscera and the resulting reflex irritation of the cardio-inhibitory centre.

The activity of this centre is decreased by filling the lungs with air, as shown by the rapid cardiac motions when this is done. This is due to reflex action.

The *cardio-accelerating centre* sends accelerating impulses to the cardiac plexus through fibres of the sympathetic nerve.

The *vasomotor centre* is located in the upper part of the floor of the fourth ventricle. From it motorial impulses are conducted to the muscles of the arteries. The activity of this centre may be influenced by reflex irritation.

A *vasodilator centre* in the medulla has not as yet been demonstrated, but it is very probable that such a centre exists.

The *sweat-centre* in the medulla predominates over the sweat-centres in the spinal cord. This centre in the medulla is double-sided; its irritation produces sweating of the whole surface of the body.

In the medulla oblongata there are certain special centres, such as a *diabetic centre*, an irritation of which produces diabetes ; a centre the irritation of which causes convulsions, etc. These centres are not in a constant tonic, active state.

The Reflex Centres in the Medulla Oblongata.

In the medulla oblongata there are found a series of nerve-centres which are purely *reflex ;* their activity is excited ordinarily by impressions received through centripetal nerves. These centres are:

1. A centre for the closure of the eyelids.
2. A centre for the act of sneezing.
3. A centre for deglutition.
4. A centre for mastication.
5. A centre for salivary secretion.
6. A centre for the act of vomiting.
7. A centre for the act of coughing.
8. A centre for the dilatation of the pupils.
9. A centre which controls all other reflex centres in the medulla.

In the description of those functions over which these various reflex centres in the medulla preside, I included their nervous mechanism and mentioned the centripetal (or sensory), the centrifugal (or motor) nerves, and the location of the centre concerned in the various functions.

The various reflex centres in the medulla ordinarily receive the impulse for their activity through a sensory nerve, but this activity may also be excited by direct stimulation, and their activity is also influenced by the quantity of the gases—viz., the oxygen and CO_2—in the blood.

THE FOURTH VENTRICLE.

Before finishing the description of the anatomy and structure of the brain, I must describe the narrow, diamond-shaped space which is known as the *fourth ventricle* of the brain. It is the space between the pons and medulla below and the cerebellum above; it is also called the *ventricle of the cerebellum.* At its upper angle it communicates above with the third ventricle through the aqueduct of Sylvius, and below with the central canal of the spinal cord.

The boundaries of the fourth ventricle are as follows:

Its *floor* is formed by the posterior surface of the pons Varolii and the medulla oblongata. Along the middle line of the floor, running longitudinally, is a fissure which terminates below at the angle formed by the divergence of the funiculi graciles and the restiform bodies, and by the expansion of the central canal. This angle with the fissure in its centre is called, from its resemblance to the point of a pen, the *calamus scriptorius.* At each side of the central fissure there is an elongated elevation, the *fasciculus teres;* this is produced by a portion separated from the anterior horn. Passing transversely across the widest part of the ventricle are the *auditory striæ*—several white fibres which pass toward the origin of the auditory nerves. Below and above these striæ on each side are shallow depressions, called the *fovea,* superior and inferior. External to the fasciculus teres on each side there is another minor elevation, called the *ala cinerea;* this is produced by the projection of a separate portion from the posterior horns.

The gray matter which covers the floor of the fourth ventricle presents several small elevated points which are the nuclei for the deep origin of several cranial nerves.

The following cranial nerves have their deep origin in the floor of the fourth ventricle:

The *sixth* or *abducent* nerve arises from a nucleus which is located near the upper part of the fasciculus teres.

The *seventh* or *facial* nerve arises from a nucleus a little below and external to the origin of the sixth nerve.

The *eighth* or *auditory* nerve arises from two nuclei. One is located at the lateral angle of the ventricle, another near the fovea inferior.

The *ninth* or *glosso-pharyngeal* nerve arises from the lower part of the floor of the ventricle, below the fovea inferior and the auditory nucleus in that region.

The *tenth* or *pneumogastric* nerve has its deep origin immediately beneath that of the ninth nerve.

The *eleventh* or *accessory* part of the *spinal accessory* nerve arises from a nucleus at the upper part of the calamus scriptorius.

The *twelfth* or *hypoglossal* nerve arises from a collection of cells in the nucleus teres which produces the elevated fasciculus teres in the floor of the ventricle.

The *fifth* or *trifacial* nerve has two roots—a motor and a sensory. The deep origin of the sensory root is in the highest part of the floor of the ventricle—viz., near the border of the superior peduncle of the cerebellum which forms the superior or antero-lateral boundary of the ventricle. The deep origin of the motor root is from a nucleus a little external to the upper part of the fasciculus teres.

The *lateral* boundaries of the fourth ventricle are: *above*, the superior peduncles of the cerebellum, which, as they pass out from under the posterior border of the testes of the corpora quadrigemina, diverge and pass outward to the cerebellar hemispheres; *below*, the fasciculi graciles and the restiform bodies, which, as they ascend, diverge and pass to the cerebellar hemispheres, forming their inferior peduncles.

The *roof* is formed *above* by the valve of Vieussens—a thin lamella of white matter which stretches between the upper borders of the superior peduncles of the cerebellum: *below*,

by a process of pia mater which passes from the inferior vermiform appendix, or middle lobe of the cerebellum, to the lower part of the medulla. This process of the pia mater is pierced by an opening called the *foramen of Magendie*, by which the cavity of the fourth ventricle communicates with the subarachnoidian space. The cavity of the fourth ventricle is lined by a delicate membrane which is covered with a layer of nucleated endothelial cells; this membrane is continuous with that which lines the third ventricle.

Projecting from the pia mater into the cavity are two vascular *choroid plexuses.* At the apex of the calamus scriptorius the cavity of the fourth ventricle communicates with the central canal in the gray matter of the medulla and of the spinal cord. Above, it communicates with the third ventricle through the aqueduct of Sylvius, the narrow fissure between the crura cerebri laterally and in front, and the anterior surface of the corpora quadrigemina behind. This fissure is covered with the gray matter which is continuous with that lining the floor of the fourth ventricle. The lining of this fissure is continuous with that lining the third ventricle above and with that lining the fourth ventricle below.

FATIGUE AND REST OF THE BRAIN.

The brain, like all other organs of the body, requires, after a period of continuous activity, periods of rest; these are manifested by the condition known as sleep.

This condition is characterized by a cessation of all psychical activities while the automatic and reflex activities continue. There is no organ which is so continuously active as the brain, and the accumulation of the products of retrograde metamorphosis resulting from such continuous activity produces fatigue.

In man this condition occurs ordinarily once in twenty-

four hours, preferably during the night, because then external influences, such as light, etc., are lessened.

During sleep there is a decrease of all physiological activities in the body, such as the activity of the heart, secretory organs, respiratory organs, etc.

Dreaming is a psychical activity of certain parts of the cerebral cortex without an awakening of the active cerebral cortex.

Hypnotism and *somnambulism* are conditions resembling sleep; during these the individual performs locomotorial motions unconsciously. This is probably due to a temporary paralysis of the gray cortical substance of the cerebrum.

Certain drugs—such as chloral, morphine, etc.—produce a condition resembling sleep.

Narcotic drugs—such as ether, chloroform, nitrous oxide, etc.—produce unconsciousness, resulting from a temporary paralysis of the cerebral cortex.

Interference with the nutrition of the brain soon causes a cessation of all its functions.

Ligation of the carotid and vertebral arteries produces total unconsciousness in from one to two minutes. The first results of the operation are tetanic convulsions and dyspnœa as the result of the irritation of the medulla by the accumulation of CO_2; finally a condition of *coma*—viz., entire unsciousness—sets in.

These experiments and observations tend to show that the metabolic processes in the brain are very active.

LECTURE XLII.

THE CRANIAL NERVES.

THE cranial nerves are those which arise from centres in the substance of the brain; they emerge from various points on the surface of the brain, pass through openings in the dura mater, and finally leave the cranial cavity through the various foramina at its base. There are twelve pairs of cranial nerves, which, in the order in which they emerge from the brain and the cranial cavity, are called as follows:

First or olfactory nerve.
Second or optic nerve.
Third or motor oculi nerve.
Fourth or patheticus nerve.
Fifth or trifacial or trigeminus nerve.
Sixth or abducent nerve.
Seventh or facial nerve.
Eighth or auditory nerve.
Ninth or glosso-pharyngeal nerve.
Tenth or vagus or pneumogastric nerve.
Eleventh or spinal accessory nerve.
Twelfth or hypoglossal nerve.

The cranial nerves may be divided, in accordance with their functions, into nerves of special sense, motor and mixed nerves.

The cranial nerves which are nerves of *special sense* are: The olfactory, or first; the optic, or second; the auditory, or eighth.

The *motor* nerves are: The motor oculi, or third; the

patheticus, or fourth; the abducent, or sixth; the facial, or seventh; the hypoglossal, or twelfth.

The *mixed* nerves are: The trifacial, or fifth; the glosso-pharyngeal, or ninth; the pneumogastric, or tenth; the spinal accessory, or eleventh.

The point from which the cranial nerves arise at the surface of the brain is called their *superficial origin;* the point or nucleus from which the cranial nerves arise from the substance of the brain is called their *deep* or *real origin.*

The First or Olfactory Nerve.

The olfactory nerves are the nerves of the special sense of *smell.* Their *superficial origin* is in the olfactory bulbs on the under surface of the frontal lobes on each side to the anterior median fissure. The olfactory bulbs are the anterior termination of the olfactory tracts; they arise by three roots from the anterior perforated space on each side, and pass forward on the under surface of the frontal lobes. The olfactory bulbs rest upon the superior surface of the cribriform plate of the ethmoid bone; from each bulb from fifteen to twenty non-medullated nerve-fibres arise, which pass downward through the openings in the cribriform plate to be distributed to the mucous membrane of the upper part of the nasal cavity.

In the cerebral hemispheres the fibres of the roots of the olfactory tracts can be traced to the psycho-sensorial region of the cortical gray substance. The seat of the centres for the sense of smell is, according to *Munk*, located in the cortical substance of the gyrus hippocampus and the uncinate convolutions; destruction of these regions on both sides is followed by a total loss of the sense of smell. The fibres ascend in the cerebral hemispheres through the internal capsule. Transverse fibres contained in the anterior commissure of the third ventricle unite the fibres of the olfactory nerves on both sides.

The olfactory bulbs must be considered as the subcortical centres of the olfactory nerves. Section of the olfactory nerves produces loss of the sense of smell. Electrical stimulation of the olfactory filaments which are supplied to the upper part of the nose produces the sensation of smell.

The physiological irritation of the olfactory nerves is produced by the particles of odorous gases as they reach the upper part of the nose.

Anosmia, or loss of the sense of smell, is caused by injuries to the olfactory bulbs and tract or to the psycho-sensorial cerebral regions.

Hyposmia—a decrease of the sense of smell—is caused by over-irritation of the olfactory nerves, and also by certain drugs, such as morphine; the effect of such drugs is due to their influence on the cortical centre.

Hyperosmia—the excessive acuteness of the sense of smell—is often observed in hysterical subjects, but is often caused by certain drugs—viz., strychnine—as the result of an irritation of the cortical centre.

The Second or Optic Nerve.

The optic nerves are the nerves of the special sense of *sight*. The nerve arises from the optic commissure, which is situated in front of the interpeduncular space at the base of the brain, and which is formed by the connection of the optic tracts. These arise by two roots from the outer border of the crura cerebri, which they cross, passing obliquely inward and forward until they meet in front, forming the optic commissure.

The *deep origin* of the fibres of the optic tract is from the nates of the corpora quadrigemina, from the corpora geniculata, and from the posterior tubercle or pulvinar of the optic thalami. These ganglionic masses must be considered the subcortical centres for the sense of sight; from them fibres pass toward the cortical substance of the occipital lobes, in which are contained the psycho-optical centres.

In the optic commissure the nerve-fibres decussate. The optic nerves, as they arise from the commissure, pass obliquely forward and outward, enter the orbit through the optic foramen; the nerve then passes through the sclerotic and choroid coats of the eyeball at its posterior aspect, and expands into the retina.

The Third or Motor Oculi Nerve.

The motor oculi is, as the name implies, a motor nerve. It supplies all the muscles of the orbit except the superior oblique and the external rectus muscles; it also supplies the iris and the ciliary muscle.

The *superficial origin* of the motor oculi is from the internal border of the crus cerebri near the anterior border of the pons Varolii. Its *deep* origin is in a nucleus in the lower part of the floor of the aqueduct of Sylvius on either side of the middle line; from this subcortical centre fibres pass to the cortex of the angular convolution of the cerebrum.

The *functions* of the motor oculi are those of a motor nerve. Paralysis is followed by : (1) Slight *ptosis*, or dropping of the upper eyelid, because fibres of the nerve also supply the elevator palpebrarum muscle.

2. Immobility of the eyeball.

3. *Strabismus :* the eyeball is drawn outward and downward.

4. Protrusion of the eyeball, on account of the action of the superior oblique, which is not paralyzed and which is not antagonized.

5. *Mydriasis*—viz., a slight dilatation of the pupil.

6. The pupil no longer reacts to light stimuli.

7. Inability to accommodate the eye for vision at short distances.

In teething children there is often observed a condition which is known as *strabismus spasticus*, due to a reflex irritation of the motor oculi nerves.

The Fourth or Pathetic or Trochlear Nerve.

The *apparent origin* of the fourth cranial nerve is from the outer border of the crus cerebri on each side, in front of the anterior border of the pons Varolii.

The *deep origin* is in a nucleus near that of the motor oculi in the gray matter of the aqueduct of Sylvius; from it fibres pass to the psycho-motorial cortical centre in the angular convolution of the cerebral surface. The fibres of both nerves decussate at their nuclei.

The *function* of the patheticus is that of a motor nerve; it supplies the superior oblique muscle of the eyeball.

Paralysis produces a decrease in the mobility of the eyeball outward and downward, and slight strabismus, the eyeball being turned slightly inward and upward, causing double vision.

The Fifth or Trigeminus Nerve.

The trigeminus arises, like a spinal nerve, by two roots—viz., a small *anterior* or *motor root*, and a larger, the *posterior* or *sensory root.* The trigeminus resembles, furthermore, a spinal nerve, in having a *ganglion* developed on its sensory root.

The *superficial origin* is from between the transverse fibres of the under surface of the pons Varolii, near the anterior border. On each side the two roots, as they emerge from this point, are separated by a few of the transverse fibres of the pons.

The *deep origin* of the sensory root is in a nucleus located in the upper part of the floor of the fourth ventricle, near its margin, and on a level with the superior peduncles of the cerebellum.

The *deep origin* of the motor root is in a nucleus which is located in the floor of the fourth ventricle, posterior and internal to the nucleus of the sensory root.

From these nuclei fibres pass to the cortical centres

located in the psycho-sensorial and psycho-motorial areas of the cerebral cortex. From their superficial origin the two roots pass together through an opening in the dura mater, and then forward to the petrous portion of the temporal bone, where the fibres of the sensory root form a ganglion called the *Gasserian ganglion.* The motor root passes forward beneath this ganglion, and is not connected with the sensory root or its ganglion within the cranial cavity.

The *Gasserian* or *semilunar ganglion* is situated upon the upper surface of the petrous portion of the temporal bone, near the apex, and above the internal meatus auditorius. The ganglion receives nerve-fibres from the carotid plexus of the sympathetic nerve.

In the cranial cavity it gives off fibres to the tentorium cerebelli and to the dura mater lining the middle fossa of the cranial cavity. From the anterior border of the ganglion arise three large branches—viz., the *ophthalmic*, the *superior maxillary*, and the *inferior maxillary* divisions.

The ophthalmic and the superior maxillary divisions consist throughout their course only of fibres from the sensory root, and are, therefore, only nerves of common sensation. The inferior maxillary division is joined outside of the cranial cavity by the fibres of the motor root, and is, from there on, a nerve of motion and of common sensation.

The Ophthalmic Division.—This is the smallest of the three divisions; it contains fibres from the cavernous plexus of the sympathetic. The ophthalmic division passes forward and divides into three branches—the lachrymal, frontal, and nasal—just before it enters the orbit through the sphenoidal fissure.

In the cranial cavity this division gives off a *recurrent branch*, which supplies the tentorium cerebelli; it contains sensory fibres and vasomotor fibres from the sympathetic.

The *lachrymal* branch contains fibres of common sensation which supply the eyeball, conjunctiva, lachrymal

gland, and the integument of the upper eyelid, and true secretory fibres for the lachrymal gland.

The *frontal* branch divides into two smaller branches—the supraorbital, which, passing through the supraorbital foramen, supplies the integument of the forehead with common sensation; the *supratrochlear* branch supplies the lower and inner part of the forehead with common sensation.

The *nasal* nerve supplies the greater part of the lining of the nasal fossa with common sensation.

Connected with the ophthalmic division of the fifth nerve is a ganglion called the *ophthalmic, lenticular,* or *ciliary ganglion:* this is about the size of a pin-head; it is located at the back of the orbit. The roots—viz., the branches which pass to the ganglion—are: (1) a *sensory branch* from the ophthalmic division of the fifth nerve; (2) a *motor branch* from a branch of the third nerve; and (3) a *sympathetic root* from the carotid plexus.

From this ganglion are given off from 6 to 10 branches—the *short ciliary nerves;* these contain: (*a*) *Motor fibres* for the sphincter pupillæ and the tensor choroideæ muscles, also those for the dilator pupillæ muscles. (*b*) *Sensory fibres* for the conjunction of the bulb, for the iris, the choroidea, and for the sclerotic coat of the eye. Irritation of these fibres produces, by reflex action, secretion of the lachrymal glands and closure of the eyelid. (*c*) *Vasomotor fibres* for the vessels of the iris, the choroidea, and the retina.

The vasomotor fibres of the ganglion are derived from its sympathetic root; motor fibres from its motor, and partly from its sympathetic roots; the sensory fibres all from its sensory root.

The Superior Maxillary Division.—This division is, like the former, a sensory nerve. From the Gasserian ganglion it passes forward and leaves the cranial cavity through the foramen rotundum in the superior surface of the great wing of the sphenoid bone. It then crosses the spheno-

maxillary fossa, enters the infraorbital canal in the floor of the orbit, and finally emerges on the face through the infraorbital foramen. In its course this division gives off branches in the cranial cavity, in the spheno-maxillary fossa, in the infraorbital canal, and on the face.

In the cranial cavity it gives off a sensory branch—the meningeal nerve—to the dura mater. *In the spheno-maxillary fossa* are given off sensory branches to the integument of the temple and side of the forehead, posterior dental branches to the molar teeth of the upper jaw, and a branch which passes to the spheno-palatine ganglion which is connected with the second division of the fifth nerve.

In the infraorbital canal this division gives off sensory branches to the canine and front teeth of the upper jaw.

On the face sensory branches are distributed to the conjunctiva and integument of the lower eyelid, to the integument of the side of the nose, the lips, and the mucous membrane of the mouth, and to the labial glands.

The *ganglion* which is connected with the superior maxillary division of the fifth cranial nerve is called the *spheno-palatine* or *Meckel's ganglion;* this is located in the spheno-maxillary fossa. Its sensory root is formed by the spheno-palatine branches of the superior maxillary division; its motor root is from the large, superficial petrosal branch of the facial nerve; its sympathetic root is formed by the large, deep petrosal branch of the carotid plexus of the sympathetic.

From Meckel's ganglion are given off sensory, motor, secretory, and vasomotor fibres.

The *sensory* fibres are distributed to the mucous membrane of the roof of the mouth, the tonsils, and of the nose; some fibres also supply the periosteum of the orbit.

The *motor* fibres are distributed to the levator palati and the azygos uvulæ muscles.

The *vasomotor* fibres are distributed to the vessels in the regions supplied by the sensory branches.

The *secretory* fibres are distributed to the glands of the mucous membrane of the nose.

The Third or Inferior Maxillary Division.—This division is given off from the lower part of the anterior border of the Gasserian ganglion; it passes forward and leaves the cranial cavity through the foramen ovale in the superior surface of the great wing of the sphenoid bone. Just after passing through the foramen this division of the sensory root of the fifth nerve unites with the motor root and divides into an anterior and a posterior portion. Prior to this division two branches are given off—viz., a *recurrent branch*, which is a sensory nerve distributed to the dura mater, and the *internal pterygoid*, which is a motor nerve for the internal pterygoid muscle.

The *anterior* portion of the inferior maxillary nerve contains most of its motor fibres; these are distributed to the masseter, buccinator, temporal, and external pterygoid muscles.

The *posterior* portion is principally a sensory nerve, but contains a few fibres from the motor root. This portion divides into three branches—viz., the auriculo-temporal, the lingual, and the inferior dental.

The *auriculo-temporal* is a sensory nerve ; its branches are distributed to the anterior portion of the external ear, the meatus auditorius externus, the integument of the temporal region, and to the temporo-maxillary articulation.

The *lingual* nerve does not contain motor fibres ; it is a sensory nerve, and by its union with the fibres of the chorda tympani—a branch from the facial nerve—it also becomes a nerve for the special sense of taste ; it is also the nerve for the sense of touch for the tongue, the roof and floor of the buccal cavity.

The *inferior dental* nerve is a sensory nerve distributed to the teeth of the lower jaw, the gums of the lower jaw, and the integument of the chin and the lower lip. Before entering the inferior dental canal the nerve gives off two

motor branches to the mylo-hyoid and to the anterior belly of the digastric muscle.

Connected with the inferior maxillary division are two ganglia—viz., the otic and the submaxillary.

The *otic* or *Arnold's ganglion* is located immediately beneath the foramen ovale ; it communicates with the internal pterygoid branch of the inferior maxillary division, with the facial and glosso-pharyngeal nerves through the small superficial petrosal nerve, and with sympathetic fibres from the carotid plexus. Its motor fibres are from the seventh and the inferior maxillary division of the fifth ; its sensory fibres also from the third division of the fifth and from the glosso-pharyngeal nerve.

From the ganglion branches communicate with the auriculo-temporal nerve, and motor branches are given off to the tensor palati and the tensor tympani muscles.

The *submaxillary ganglion* is situated above the lower portion of the submaxillary gland. The ganglion receives fibres from the chorda tympani ; these are secretory fibres, vasodilator fibres which are distributed to the gland, and motor fibres which are distributed to the non-striated fibres of the duct of the submaxillary gland.

The ganglion receives sensory fibres from the lingual nerve, and sympathetic fibres from the plexus surrounding the facial artery.

The sensory fibres from the ganglion are distributed to the gland, its duct, and to the side of the tongue.

LECTURE XLII.

THE CRANIAL NERVES (*continued*).

The Sixth or Nervus Abducens.

THE abducent is a motor nerve for the external rectus muscle of the eye.

The *superficial origin* of the sixth nerve is from the sides of the pyramid near the border of the pons.

The *deep origin* is in the floor of the fourth ventricle posterior to that of the motor root of the trifacial nerve.

The nerve enters the orbit through the sphenoidal fissure. Paralysis of the nerve produces strabismus, the bulb of the eye being turned inward.

The Seventh or Facial Nerve.

The seventh or facial nerve is the motor nerve for all muscles of the face, also for the buccinator, the platysma myoides, the stylo-hyoid, and the posterior belly of the digastric.

The *deep origin* is in a nucleus on the floor of the fourth ventricle, below and external to that of the abducent nerve. The *superficial origin* is from the lateral tract of the medulla oblongata.

From its superficial origin the nerve passes forward and enters the internal meatus auditorius in the petrous portion of the temporal bone, together with the auditory nerve. In the floor of the meatus the facial nerve then enters the aqueductus Fallopii, and finally leaves the cranial cavity through the stylo-mastoid foramen, penetrates the parotid gland, and divides into its many

branches. The facial nerve gives off within the aqueductus Fallopii two branches—the tympanic and the chorda tympani.

The *tympanic branch* supplies the stapedius muscle.

The *chorda tympani* is a nerve for the special sense of taste, and also the nerve for the tactile sense of the tongue. In its course the nerve unites with the lingual branch of the third division of the trigeminus. It has been observed that some fibres of the facial nerve have their deep origin in the nucleus of the glosso-pharyngeal, and it is supposed that these fibres constitute those of the chorda tympani.

In the internal meatus the facial nerve communicates by several fibres with the auditory nerve. The large superficial petrosal nerve is also given off from the facial in this region; by it the facial communicates with Meckel's ganglion.

In the aqueduct of Fallopius the facial nerve communicates with the otic ganglion by the small superficial petrosal nerve, and with the sympathetic plexus in that region. After its exit from the stylo-mastoid foramen the facial nerve supplies motor nerves to the stylo-hyoid, the posterior belly of the digastric, the occipital, the buccinator, the platysma myoides, the muscles of the external ear, and to all the muscles of the face.

In the face the branches of the facial nerve anastomose with branches of the trigeminus. After the exit through the stylo-mastoid foramen the facial nerve also communicates with the glosso-pharyngeal, with the vagus, with the sympathetic plexus surrounding the carotid artery, and with the three divisions of the trigeminus.

The facial nerve is the nerve for the voluntary motions of the muscles of the face, by which we are able to give to it the various expressions. To a certain extent the facial nerve also partakes in the nervous mechanism of speech and of the act of deglutition.

The Eighth or Auditory Nerve.

The *superficial origin* of the eighth or auditory nerve is from the side of the medulla oblongata, from a groove between the olivary body and the restiform body.

The *deep origin* of this nerve is in two nuclei, one of which is situated at the lateral angle of the fourth ventricle, the other on the floor of the ventricle posterior and internal to the former nucleus.

From its superficial origin the nerve passes forward and enters the meatus auditorius internus together with the facial nerve, and is connected with it by several fibres. In the meatus the nerve divides into two branches—viz., the *cochlear*, which is distributed to the cochlea, and the *vestibular*, which is distributed to the vestibule and the semicircular canals.

The auditory nerve has two functions. First, it is the nerve for the special sense of *hearing.* Irritation of the nerve produces the sensation of hearing; injury or destruction produces deafness.

Second, the auditory nerve controls the motions which are required for the maintenance of the *body equilibrium.* This function of the nerve is localized in the portion which is distributed to the semicircular canals. Destruction of these does not produce any disturbances of the sense of hearing, but is followed by vertigo, dizziness, and disturbances of the body equilibrium.

The Ninth or Glosso-Pharyngeal Nerve.

The glosso-pharyngeal is a mixed nerve ; it is the nerve of *common sensation* for the surface of the tongue, pharynx, fauces, and the tonsils, and a nerve of the special sense of *taste* for those parts of the tongue which it supplies ; it also sends motor filaments to the pharynx. The *deep origin* of this nerve is in a nucleus in the floor of the

fourth ventricle, below the nucleus of the auditory, and above that of the vagus nerve.

The *superficial origin* is from the side of the medulla oblongata, from the groove between the olivary body and the restiform body above the superficial origin of the vagus.

The glosso-pharyngeal leaves the cranial cavity through the jugular foramen. In passing through this foramen the nerve presents two ganglia—viz., the jugular and the petrous.

The *petrous ganglion* is the larger of the two; through it the glosso-pharyngeal nerve communicates with the pneumogastric, with the sympathetic, and with the facial nerve.

The *jugular ganglion* is a small ganglionic mass separated from the former.

The *motor* branches of the glosso-pharyneal nerve supply the constrictors of the pharynx, the palato-glossus, the palato-pharyngeus, the stylo-pharyngeus muscles.

The Tenth or Vagus or Pneumogastric Nerve.

The *deep origin* of this nerve is in a nucleus in the lower part of the floor of the fourth ventricle; this nucleus is situated below, and is continuous with, the nucleus of the glosso-pharyngeal nerve.

The *superficial origin* is from the side of the medulla oblongata, below that of the glosso-pharyngeus.

The vagus passes forward from its origin and leaves the cranial cavity in a sheath, together with the spinal accessory nerve, through the jugular foramen. The vagus has a greater distribution than any other cranial nerve. It is composed of sensory and the motor fibres; it passes through the neck, the thorax, and the upper part of the abdomen. The *motor* fibres are distributed to the vocal organs, to the respiratory apparatus, to the pharynx, the œsophagus, to the heart, and to the stomach. Its *sensory*

fibres are distributed to the larynx and to the respiratory tract.

Immediately below the jugular foramen the vagus presents a ganglion called the *ganglion of the root of the vagus;* this ganglion is connected with the accessory portion of the spinal accessory nerve, with the petrous ganglion of the glosso-pharyngeal, with the facial, and with the superior cervical plexus of the sympathetic nerve.

Beneath this ganglion there is a second ganglionic enlargement, called the *ganglion of the trunk of the vagus;* this communicates with the hypoglossal nerve, with the superior cervical plexus of the sympathetic, with the first and second cervical nerves. Beneath this ganglion the vagus gives off many branches with various functions, as follows:

Motor fibres to the muscles of the neck, principally derived through the spinal accessory.

Sensory fibres through the auricular branch to the tympanum and middle ear.

Motor fibres in the pharyngeal branch to the muscles of the pharynx, soft palate, and upper part of the œsophagus. The vagus, therefore, to a great extent, partakes of the nervous mechanism of the act of deglutition.

Sensory and *motor fibres,* through the superior laryngeal nerve, to the mucous membrane of the larynx and the muscles which produce tension of the vocal cords.

Motor fibres to the muscles of the larynx which close and enlarge the glottis, and which relax the vocal cords, through the inferior laryngeal nerve.

Motor fibres to the non-striated fibres of the œsophagus.

Motor and *sensory fibres* to the lungs. The influence of these nerves on the respiratory function has already been described under the subject of respiration.

Inhibitory fibres to the heart.

Sensory fibres to the heart.

Motor and *sensory fibres* to the stomach.

Section of the vagus in the neck is followed by many serious disturbances which finally cause death. Among the most prominent disturbances may be mentioned the increased cardiac action and the decreased and labored respirations. Aside from these, various motor disturbances are caused, due to paralyzation of muscles of the neck, of the larynx, pharynx, and œsophagus.

The Eleventh or Spinal Accessory Nerve.

This nerve consists of two parts—viz., the accessory part to the vagus, and the spinal portion.

The *deep origin* of the *accessory* portion is in a nucleus in the floor of the fourth ventricle at the top of the calamus scriptorius; it extends downward as far as the intermediary lateral tract of the gray matter of the cord, to the deep origin of the spinal portion of the nerve.

The *superficial origin* of the *accessory* portion is from the side of the medulla below that of the vagus.

The *superficial origin* of the *spinal* portion is from the lateral tract of the cord as far as the sixth cervical nerve.

The *accessory portion* of the nerve passes from its origin forward through the jugular foramen with the vagus; it is then connected by filaments with the ganglion of the root of the vagus and with the spinal portion of the spinal accessory; it then joins the trunk of the vagus, passes through the ganglion of the trunk, and is distributed to the superior laryngeal and the pharyngeal branches of the vagus.

This portion of the spinal accessory contains motor and cardio-inhibitory fibres.

The *spinal portion* of the spinal accessory nerve ascends from its superficial origin, then enters the cranial cavity through the foramen magnum, then passes outward and leaves the cranial cavity through the jugular foramen in the same sheath with the pneumogastric nerve; it contains sensory fibres from the first and second cervical nerves.

This portion of the spinal accessory supplies principally *motor* fibres to the trapezius and sterno-mastoid muscles.

The Twelfth or Hypoglossal Nerve.

This nerve supplies motor fibres to the muscles of the tongue, the genio-hyoid, and thyreo-hyoid muscles.

Its *deep origin* is in a nucleus in the floor of the fourth ventricle, in the lower part near the median line.

Its *superficial origin* is from the side of the medulla, from the groove between the pyramid and the olivary body.

The hypoglossal leaves the cranial cavity through the anterior condyloid foramina.

It is, at its root, a purely motor nerve, but in its course it receives vasomotor fibres from the cervical sympathetic, which are distributed to vessels of the tongue. Section of the hypoglossal produces total paralysis of the tongue.

LECTURE XLIV.

THE SPINAL CORD.

Anatomy and Structure.

The spinal cord is that portion of the cerebro-spinal axis which is contained in the spinal canal; it does not fill the spinal canal. The cord is covered by three membranes—viz., the dura mater, the arachnoid, and the pia mater. The dura mater of the cord is not adherent to the walls of the spinal canal, but surrounds the cord loosely as a tubular sheath; the membranes of the cord are continuous with those of the brain. The dura mater is pierced on its sides for the transmission of the roots of the spinal nerves.

The spinal cord is from 17 to 18 inches long; it extends from the upper border of the atlas to the lower border of the first lumbar vertebra, where it terminates in a thin, slender extremity called the *filum terminale*. The weight of the spinal cord divested of its membranes is about 1½ ounces. The cord is rounded and somewhat flattened; it is not of an equal thickness, but is slightly thicker in its upper part, and presents in the cervical and in the lumbar regions enlargements which are due to greater masses of gray matter in the interior of the cord.

The cord is divided on its surface into symmetrical lateral halves by two fissures. One, the *anterior median fissure*, passes along the whole length of the anterior aspect of the cord; and the other, the *posterior median fissure*, passes along the whole length of the posterior aspect. The anterior fissure is wider, but not as deep as

the posterior. These halves are connected by a transverse band of nerve-tissue which is called the *commissure of the cord*. The anterior half of this consists of white medullated fibres and is called the *anterior* or *white commissure*. The posterior half is composed of nerve-fibres and neuroglia, it has a grayish color, and is called the *posterior* or *gray commissure*. Each lateral half of the cord presents laterally to the anterior and posterior median fissure a shallow longitudinal fissure called the *anterior* and *posterior lateral fissures*. These several fissures divide each lateral half of the cord on its surface into *four columns*, which are called respectively the anterior, the lateral, and the posterior columns of the cord.

The *anterior column* is the portion between the anterior median and the antero-lateral fissures.

The *lateral column* is the largest; it is the portion between the antero-lateral and the postero-lateral fissures.

The *posterior column* is the portion between the posterior median and the postero-lateral fissures. At each side of the posterior median fissure a narrow segment of the posterior columns protrudes somewhat; this is also called the *posterior median column*, or the *column of Goll*. The portion of the posterior column external to this column of Goll is called the *posterior external column*, or the *cuneate fasciculus*.

From the grooves in each lateral half of the cord—viz., from the anterior and the posterior lateral fissures—arise the roots of the spinal nerves. The anterior or motor roots arise from the anterior, the posterior or sensory roots from the posterior, lateral fissure.

The spinal cord, like all central organs of the cerebro-spinal nervous system, consists of white and gray nerve substance, the former being arranged externally, the latter internally.

The *white matter* of the cord constitutes the mass of the columns; it is composed of medullated nerve-fibres, of

neuroglia, of blood-vessels, and of delicate septa from the pia mater which pass inward between the bundles of fibres supporting it.

The medullated fibres of the white substance of the cord are largely *longitudinal fibres* arranged in bundles or fasciculi. There are also *transverse* or *oblique fibres;* these are: (*a*) the fibres which pass transversely from one lateral half of the cord to the other across the anterior or white commissure; (*b*) the fibres from the roots of the spinal nerves—these pass transversely, at some points in an oblique course, through the white substance into the gray matter; (*c*) fibres which pass transversely through the anterior commissure from the anterior horn of the gray matter on one side to the anterior horn in the other side of the cord; and (*d*) fibres which arise from cells in the gray matter and enter the white substance, passing in it obliquely or horizontally, being sometimes continuous with the longitudinal fibres.

The fibres of the white matter are separated into several distinct bundles, tracts, or fasciculi. The observation of pathological lesions of these bundles and many experiments have demonstrated that the fibres of these bundles possess certain special functions.

The several bundles or fasciculi of nerve-fibres of which each column of the cord is composed are as follows:

The *anterior column* of the cord consists of two bundles—viz., (1) the direct pyramidal fasciculus, and (2) the fundamental fasciculus.

1. The *direct pyramidal fasciculus* comprises the portion of the anterior column near the anterior median fissure; it consists of longitudinal fibres which ascend and are continuous with fibres of the pyramid of the medulla oblongata on the same side. The fibres of the pyramids are continuous with the superficial longitudinal fibres of the pons Varolii; these pass forward as the fibres of the crusta of the crura cerebri. In the cerebral hemispheres part of these fibres

pass directly through the internal capsule to the cortical gray substance of the psycho-motorial region, and the remainder pass to the corpus striatum. The fibres of the pyramids are *motor*. Those fibres of the pyramids which are continuous with the fibres of the direct pyramidal fasciculus of the same side *decussate* as they pass to the cerebral hemispheres through the pons and the crura cerebri.

2. The *fundamental fasciculus* comprises the remaining portion of the anterior column ; its fibres ascend and enter the deeper portion of the medulla—viz., the formatio reticularis. The fibres of the formatio reticularis of the medulla are continuous with the fibres of the same structure of the pons, and these are continuous with the fibres of the tegmentum or upper layer of the crura cerebri. Entering the cerebral hemispheres, the fibres of the tegmentum pass upward, either directly to the psycho-sensorial area of the cortex or to the subcortical sensory centres, the optic thalami.

The *lateral column* of the cord consists of four bundles—viz., 1, the anterior radicular zone ; 2, the cerebellar column ; 3, the mixed lateral column ; and 4, the crossed pyramidal fasciculus.

1. The *anterior radicular zone* comprises the anterior portion of the lateral column ; its fibres ascend through the lateral tracts of the medulla on the same side, and are continued upward as fibres of the formatio reticularis of the pons.

2. The *cerebellar column* comprises the posterior and peripheral portion of the lateral column. The fibres of this fasciculus ascend under the lateral tract of the medulla on the same side, then pass into the restiform body of the medulla, and from here pass to the cerebellum as fibres of the inferior peduncles of the cerebellum.

3. The *mixed lateral column* comprises the portion of the lateral column behind the anterior radicular zone and in-

ternal to the cerebellar column. The fibres of this bundle ascend into the lateral tract of the medulla and then pass up into the formatio reticularis of the medulla and the pons.

4. The *crossed pyramidal fasciculus* comprises the portion of the lateral column internal to the mixed lateral column; its fibres ascend, cross the anterior median fissure in the lower part of the medulla, and enter the pyramid on the opposite side.

The *posterior column* of the cord consists of two bundles —viz., (1) the posterior median, or the column of Goll, and (2) the cuneate fasciculus, or Burdach's column.

1. The *column of Goll* comprises the portion near the posterior median fissure; its fibres are continued upward as fibres of the fasciculus gracilis of the medulla; the fibres of this terminate in the nucleus gracilis.

2. The *cuneate fasciculus* comprises the outer portion of the posterior column; its fibres are continued upward as the fibres of the funiculus cuneatus of the medulla, and terminate in a mass of gray matter called the nucleus cuneatus.

The course of the longitudinal fibres of these various bundles cannot be traced by dissection. The method generally adopted to determine their course is careful section of the various bundles, and is based upon the fact that nerve-fibres undergo degeneration when the connection with their centre is severed.

The special function of the fibres of the several bundles is determined by observing the disturbances produced by experimental section or by pathological lesions of the various parts of the cord.

The *gray matter* of the cord is contained in its centre, and is so arranged that each lateral half contains a crescentic mass of gray matter, which is directed with its concavity outward and with its convexity toward the median line.

The two crescentic masses are connected by a transverse

band of gray matter, which forms the posterior part of the commissure of the cord, and is also called the posterior or gray commissure. This is pierced in the centre by a delicate canal which extends through the entire length of the cord; this is called the *central canal of the cord;* it is lined with endothelium and communicates with the fourth ventricle of the brain. On a transverse section of the cord the gray matter in the centre has the form of the letter X.

The crescentic mass of gray matter in each lateral half of the cord presents an anterior and a posterior horn or genu.

The *anterior horn* is thick, rounded, and directed forward and outward toward the antero-lateral fissure, not reaching, however, its surface; from the anterior horn arise the fibres of the anterior or motor roots of the spinal nerves.

The *posterior horn* is thin and slender, and is directed outward and backward toward the postero-lateral fissure extending to its bottom surface; from the posterior horn arise the fibres of the posterior or sensory roots of the spinal nerves.

The gray matter of the cord consists of ganglion-cells, of a delicate network of nerve-fibrillæ which are continuous with the protoplasmic processes of the ganglion-cells, and of medullated nerve-fibres which frequently branch off, finally become non-medullated and communicate with the delicate fibrillar network; behind, and in front of the central canal, nerve-fibres pass from one side to the other across the gray commissure. The ganglion-cells are situated in groups in the anterior and posterior horn; those in the anterior horn are large, pear-shaped, unipolar cells, the pole of which is continuous with the axis-cylinder of a fibre of the anterior or motor root of a spinal nerve. These ganglia communicate with the fibrillar network of the gray substance by delicate protoplasmic processes from their body. These ganglia must therefore be regarded as *motor centres.*

The ganglia in the posterior horn are smaller; the body

of each is spindle-shaped and communicates by its poles with the fibrillar network in the gray substance. These ganglia are surrounded by the tree-shaped terminals of the fibres of the sensory roots. It is evident that these fibres impart impulses to the ganglia, which they embrace with their branching terminations, and must therefore be considered as *sensory centres.*

From the axis-cylinder of many of the longitudinal fibres of the white substance, delicate fibrillæ pass horizontally into the gray substance, terminating in tree-like branches which embrace the ganglion-cells in the gray matter. These tree-like terminations of nerve-fibrillæ in the gray matter are called *collaterals.*

The delicate nerve-fibrillæ and collaterals in the gray matter serve to conduct impressions in this portion of the cord and between the ganglion-cells.

The Functions of the Spinal Cord.

The functions of the spinal cord may be described under three headings—viz., reflexion, conduction, and transference.

The central functions of the spinal cord are those of a *reflex centre.*

The centrifugal fibres of the cord do not conduct voluntary impressions alone, but also those which are conducted to the cord from the periphery by a centripetal or sensory nerve to a centre in the cord, and which are then reflected or transmitted from this centre to the centrifugal fibres. Motions and functions so produced are involuntary; they are produced unconsciously and are called the *reflex motions* or *acts*. Many centres in the cord possess the property of transferring impressions received in this manner to centrifugal nerves. We distinguish three varieties of reflex motions—viz.: 1. *Single reflex motions*, consisting of a single muscular contraction as the result of a peripheral irritation of a sensory nerve. An example is the sudden

contraction of the biceps muscle, caused by a blow on the arm over the region of this muscle.

2. *Extensive non-co-ordinated reflex motions.* These are tonic or tetanic convulsive contractions of one or several groups of muscles. The contractions are characterized by being purposeless and non co ordinated. Such convulsive reflex motions are caused by an excessive irritation of the spinal cord. Certain drugs, such as strychnine, nicotine, etc., when given in large doses, increase the irritability of the spinal cord, so that the least irritation of the skin excites the most violent convulsive reflex motions.

3. *Co-ordinated reflex motions* are those in which muscular contractions of certain muscle groups are produced, caused by the peripheral irritation of a sensory nerve, and resulting in motions which ordinarily are produced by an effort of the will and with a certain purpose.

The reflex activity of the spinal cord is best demonstrated when it is severed from the brain. Cold-blooded animals—for example, frogs—are used for this demonstration, because in them the spinal cord retains its reflex activity longer than in warm-blooded animals. If the spinal cord is severed from the brain there will be a loss of voluntary motor power and loss of sensation below the point of section. If a frog is decapitated it is unable to make any voluntary motions; but if its skin is touched it will make the most complicated motions, such as hopping, drawing up the legs, etc. The various motions which we make during sleep—such as rolling over, scratching where the skin is irritated, the closing of the palm of the hand or drawing up of the foot when tickled—are all voluntary motions performed during unconsciousness.

The spinal cord is, furthermore, the seat of a number of reflex centres which preside over certain functions of the body.

These special reflex centres in the cord are:

1. A centre for the dilatation of the pupils; this is located

in the dorsal region between the first and second dorsal vertebræ. The centripetal fibres are contained in the optic nerve, the centrifugal fibres in the cervical portion of the sympathetic.

2. The centre of micturition.
3. The centre of defecation.
4. The centre for the erection of the penis.
5. The centre for the ejaculation of the semen.
6. The centre for the act of labor.
7. The centre for the secretion of sweat.
8. Vasomotor and vasodilator centres.

These centres are located in various parts of the spinal cord, and, although they retain their activity after section of the cord, they are normally governed by centres in the medulla and must therefore be considered as centres subordinate to those of the medulla.

Many reflex motions may be suppressed by an effort of the will—for instance, the closing of the eye when the eyeball is touched, the reflex motions produced as the result of an irritation of the skin, etc. This voluntary inhibition of reflex motions is, however, limited. No reflex motions can be suppressed by an effort of the will which ordinarily cannot be voluntarily produced; again, many reflex motions, such as ejaculation of semen, the motions of the iris, the act of labor, etc., cannot be suppressed by an effort of the will. According to certain authors there exists in the brain an automatic inhibitory centre which governs the reflex irritability of the cord.

Excessive irritation of a centripetal or sensory nerve suppresses reflex motion.

The reflex irritability of the spinal cord may also be increased or decreased by certain drugs; among these are strychnine and nicotine, which increase, and chloroform, morphine, and bromides, which decrease the same.

The importance of the spinal cord as an organ of *conduction* has already been demonstrated by its structure

and anatomical relation. All impulses from the periphery to the centres in the cord, medulla, or other parts of the brain, and from these centres to the periphery, are conducted through the various parts of the spinal cord in such a manner that certain parts always conduct the same kind of impressions.

The experiments of *Brown-Séquard* and others regarding the conduction of various impressions in the cord have demonstrated the following:

1. *Sensory impressions* are conveyed to the cord by fibres of the posterior roots of the spinal nerves, and, passing through the posterior columns into the gray substance, they are conducted in this to the brain. In the gray substance the sensory impressions are conducted upward on the side at which they enter for a short distance only, and then decussate to the other side, to be conducted to the brain. Section or disease of one posterior half of the cord is followed by a loss of sensation on the opposite side of the body.

2. *Voluntary motor impulses* originate in the brain and are conducted along the fibres of the superficial layer of the crura cerebri and along the longitudinal fibres of the pons to the pyramids of the medulla. In the anterior part of the medulla there takes place a decussation of the voluntary motor impulses. They are then conducted downward in bundles of the anterior and lateral columns of the spinal cord in the opposite half, and are finally conducted from the cord by the fibres of the anterior roots of the spinal nerves.

The decussation of the motor impulses does not take place in the cord, but in the medulla. Section or disease of the anterior and lateral tracts of the cord on one side is followed by paralysis or loss of voluntary motor power on the same side of the body below the point of section. The fact that section of the anterior and lateral tracts of the cord is followed only by temporary paralysis (provided the

section does not include the gray matter) tends to show that voluntary motor impressions are also conducted along the gray matter of these portions of the cord.

The various other impressions—such as tactile impressions, inhibitory impressions, and the impressions of temperature—are conducted in separate portions of the cord; they all undergo decussation in the cord.

The meaning of the term *transference of impulses* I have already described when speaking of the functions of the nerve-centres. This property or function is possessed by many of the ganglion-cells or centres of the spinal cord. For example, the pain felt in the knee-joint as an early symptom of disease of the hip-joint, is due to the transference of a sensory impression from a sensory nerve of the hip-joint to one of the knee-joint.

The normal activity of the spinal cord and its irritability are dependent upon a normal circulation.

LECTURE XLV.

THE SPINAL NERVES.

THE thirty-one pairs of spinal nerves arise from the spinal cord, pass through openings in the membranes of the cord, and leave the spinal canal through the intervertebral foramina. The spinal nerves are divided into *cervical*, *dorsal*, *lumbar*, and *sacral*. Each spinal nerve arises from the cord in two roots—an anterior and a posterior.

The *anterior* root arises from the antero-lateral fissure, the *posterior* root from the postero-lateral fissure, of the cord.

Charles Bell detected in 1811 that the *anterior* root consists of *centrifugal* or *motor* fibres, and that the posterior root consists of *centripetal* or *sensory* fibres.

The two roots emerge through separate openings in the dura mater. In the intervertebral canal the sensory root presents a *ganglion* immediately behind this; the two roots unite, forming a mixed nerve, which, as such, emerges through the intervertebral foramen and divides into an *anterior* and *posterior* branch, each of which contains both sensory and motor fibres.

Magendie found in 1822 that the motor root of the spinal nerves also contains sensory fibres. This is shown by the fact that stimulation or section produces pain. This is due to the fact that fibres from the sensory root pass into the motor root at the point of union of the two, and then pass centrally in the motor root. If the sensory root is cut, then the motor root loses its sensibility. The sensibility of the motor root is termed *recurrent sensibility*. Experimental section of the roots has shown the following:

1. Section of the *anterior* or *motor* root produces (*a*) pain

at the moment of section, due to the recurrent sensibility of the motor root; (*b*) a sudden contraction of the muscles supplied by that nerve, caused by the mechanical irritation produced by the section.

2. After section the muscles supplied by that nerve are paralyzed; there is no loss of sensation or sense of touch in the same region.

3. Stimulation of the peripheral stump produces muscular contraction and pain for some time after section.

4. Stimulation of the central stump is not followed by any results.

5. Section of the *posterior* or *sensory* root produces pain at the moment of section.

6. At the moment of section a reflex motion is produced as the result of the mechanical irritation.

7. Section of this root is followed by loss of sensation and sense of touch in the region supplied by that nerve, whereas motor power remains intact in that region.

8. Irritation of the peripheral stump has no result; irritation of the central stump produces pain and reflex motion.

9. The peripheral stump of the nerve degenerates after section of its root.

10. The spinal cord is the nutritive centre for the motor root, the spinal ganglion for the sensory root.

The anterior roots of the spinal nerves contain the following centrifugal fibres:

1. *Motor* fibres for the voluntary striated muscles of the trunk and the extremities.

2. *Motor* fibres for the involuntary non-striated muscular fibres of certain organs, as, for example, those of the uterus, the bladder, etc.

3. *Motor* fibres for the muscular fibres of the blood-vessels—viz., *vasocontractor* fibres.

4. *Inhibitory* fibres for the contraction of the muscular fibres of the blood-vessels—viz., the *vasodilator* fibres.

5. *Secretory* fibres for the sweat glands.

6. *Trophic* fibres.

The posterior or sensory roots contain the following centripetal fibres:

1. *Sensory* fibres for the internal organs and the skin of the body, exclusive of the anterior part of the head, the face, and the interior of the head, which are supplied by cranial nerves.

2. Nerves for the sense of *touch* for the skin of the same region.

The fibres from the sensory roots also conduct, from the periphery to the centre, stimuli which result in the production of reflex motions.

The sensory fibres of the trunk of a mixed nerve are distributed to the skin of that region the muscles of which are supplied by the motor fibres from the same trunk.

The *course* of the fibres of the roots of the spinal nerves in the cord varies.

The fibres of the *anterior* roots enter the cord in several bundles; these pass horizontally or obliquely toward the anterior horn of the gray matter. Most of the fibres are continuous with the poles of the unipolar ganglion-cells in the anterior horn, some with the anterior, some with the middle, and some with the internal group of the ganglion-cells. Again, some of the fibres pass to the gray matter of the posterior horn, but are not connected with the cells there. Another bundle of fibres passes across the gray commissure to the anterior cornu on the opposite side. Some of the fibres of the anterior root also pass directly in the lateral column of the cord without any connection with the ganglion-cells in the cornua.

The fibres of the *posterior* roots enter the cord and pass to the gray matter of the posterior horn, in which the axis-cylinder of the fibres breaks into several branches, which surround the ganglion-cells.

THE SYMPATHETIC NERVOUS SYSTEM.

The sympathetic nervous system is distributed all over

the body; it contains numerous ganglia and communicates with the nerves and central organs of the cerebro-spinal nervous system. The trunk of the sympathetic consists of a connected chain of ganglia placed at either side of the spinal column; this pre-vertebral chain of ganglia communicates by nerve-fibres, called the *rami communicantes*, with the roots of the spinal nerves.

From each ganglion a ramus communicans passes toward the point of union of the roots of a spinal nerve. The ramus communicans contains both centripetal and centrifugal fibres.

From the pre-vertebral chain of the sympathetic ganglia larger trunks pass into the thoracic and abdominal cavities, forming there plexuses containing numerous ganglia; and from these plexuses fibres are distributed to the various organs.

The function of the ganglia of the sympathetic nervous system is principally that of *trophic centres*. Some ganglia are, however, the *physiological centres* for the nerves arising from them. Such ganglia are, for instance, the automatic ganglia of the heart, the ganglia of the mesenteric plexus of the intestines, of the uterine plexus, etc. The activity of these ganglia is independent of any nerve connection with the cerebro-spinal system. The functions of these ganglia, and of the nerves connected with them, will continue even if all connections with the cerebro-spinal system are severed.

Ordinarily the activity of these independent ganglia is influenced by inhibitory or accelerating impulses received through fibres from the cerebro-spinal system. Many ganglia are *reflex centres* which reflect stimuli received from the periphery to the centrifugal fibres, thus producing a reflex act.

The function of many fibres of the sympathetic system depends upon their connection with the cerebro-spinal system.

The function of the fibres of the sympathetic nervous system is the same as that of all other nerve-fibres—viz., the conduction of impulses—and, according to the character of the impulse they convey, the sympathetic nerve-fibres may be classified into sensory fibres, motor fibres, secretory fibres, inhibitory fibres, trophic fibres.

The *sensory* fibres are distributed to the internal organs. Ordinarily we do not perceive the processes taking place in these organs. We, for instance, do not feel the moving of the ingesta in the alimentary canal, the walls of which are supplied by sensory fibres from the sympathetic. If, however, these sensory nerves are abnormally irritated, an increased peristalsis and pain are produced, which shows that these sensory fibres are in connection with the cerebral psycho-sensorial centres. The fact that ordinary physiological irritation of the sensory fibres of the sympathetic does not produce the sensation of touch, is due to the fact that these nerves are not supplied with sensory terminal apparatus like the sensory nerves of the cerebro-spinal system.

The *motor* fibres are distributed only to *involuntary* fibres—viz., to the muscular fibres of the heart, the blood-vessels, the stomach and intestinal canal, and many internal organs.

The motor fibres are therefore not in direct connection with the psycho-motorial centres. There exists, however, a certain influence of the cerebrum upon the motor functions of the sympathetic; this is best shown by the effect of certain psychical events, such as fear, shock, fright, etc., upon the heart, blood-vessels, intestinal canal, etc.

The *secretory* fibres of the sympathetic are distributed to many secreting glands—for example, to the salivary glands and to the secreting glands of the alimentary canal.

The sympathetic contains fibres which conduct *inhibitory impulses* from the periphery to the centre, and those which convey *inhibitory impulses* from the centre to the

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periphery. A sudden irritation of the abdominal sympathetic produces, by reflex, a cessation of the heart's action.

The activity of the fibres of the sympathetic is induced either by reflex action or by the automatic activity of their ganglia.

QUESTIONS AND EXERCISES.

SUBJECT.—*The Physiology of the Nervous System. Lectures XXXIV.–XLV. inclusive.*

679. Name the divisions of the nervous system.

680. Name the organs composing the cerebro-spinal and those composing the sympathetic nervous system.

681. Describe the structure of nerve-cells.

682. Give the distribution and structure of the gray nerve-substance.

683. Name the various kinds of nerve-centres, their distribution, general structure, and their general properties and functions.

684. What is a reflex act?

685. How are the centres classified in accordance with their special functions?

686. What do you understand by simple and what by co-ordinated reflex motions? Give an example of each.

687. Explain what you understand by the automatic, reflex, voluntary activity of a nerve-centre.

688. Give the general structure of a nerve-trunk.

689. Describe the structure of a medullated and a non-medullated nerve-fibre.

690. Give the general properties and functions of nerve-fibres.

691. Give the laws regulating the conduction of impulses through nerve-fibres.

692. What is the rapidity with which an impulse is estimated to be conducted through nerve-fibre in the human subject?

693. What is the cause of nerve activity?

694. What do you understand by nervous irritability?

695. What is the effect of the application of artificial stimuli to nerves?

696. Give the chemical properties and composition of nerve-tissue, and name the principal products of the retrogressive metamorphosis in nerve-tissue.

697. How is the nutrition, growth, and regeneration of nerve-tissue maintained?

698. Name the parts which compose the brain.

699. Name the membranes of the brain and their uses.

700. What is the weight of the human brain?

701. What is the cerebrum? Name its lobes and fissures.

702. What are the sulci, and what do they indicate?

703. Name the principal anatomical points on the under surface of the cerebrum.

704. Name the basal ganglia of the brain.

705. Describe the distribution of white and gray nerve-substance in the cerebrum.

706. What is the function of the gray cortical substance of the cerebrum?

707. What is the function of the white matter of the cerebrum?

708 Define the psycho-motorial, the psycho-sensorial, the psycho-acoustic, and the psycho-visual areas on the cortical gray substance of the cerebrum.

709. Describe and give the functions of the corpora striata; thalami optici; corpora quadrigemina.

710. What would be the effect of pressure upon, or destruction of, the psycho-motorial area on one side of the cerebrum?

711. Give the boundaries of the fifth, the lateral, and the third ventricles of the brain.

712. Name the boundaries of, and the parts contained in, the interpeduncular space.

713. What is the corpus callosum? the fornix? the velum interpositum?

714. Give the location, the cross-structure, and the functions of the cerebellum.

715. Name the peduncles of the cerebellum.

716. Give the cross structure and functions of the pons Varolii.

717. Give the structure of the crura cerebri and their functions.

718. Give the anatomy and structure of the medulla oblongata.

719. Give the functions of the medulla.

720. Name the more important centres located in the medulla.

721. Give the cross-anatomy and the structure of the spinal cord.

722. Name some of the more important centres of the spinal cord.

723. Name the twelve pairs of cranial nerves, and give their superficial and deep origins, their functions and general distribution.

724. Give the number and classification of the spinal nerves.

725. Describe the origin and general arrangement of the spinal nerves.

726. Give the course of a sensory impulse from the hand to the brain, and the course of a voluntary motor impulse from the brain to the hand.

727. Give the general arrangement of the sympathetic nervous system.

728. Describe the nervous mechanism of the acts of deglutition, defecation, and micturition.

729. What do you understand by paralysis, anæsthesia, cretinism, and coma?

LECTURE XLVI.

THE SENSES AND THE SENSORY ORGANS.

The animal body is provided with certain organs and mechanisms by which the mind, through the medium of the nervous system, perceives the various occurrences in the external world and any changes in the body.

The mind perceives these various sensory impressions as the result of the stimulation of psycho-sensorial centres in the cerebrum. These centres have each a special function, so that through the activity of such a centre the mind perceives sensory impressions of one kind; again, these centres are ordinarily stimulated by impressions conducted to them by special nerves.

The various sensory impressions which the mind thus perceives may be classified into special and general.

General or *common sensations* are those by which the mind recognizes changed conditions of the body.

The sensations of *hunger*, *thirst*, *fatigue*, *discomfort*, *disgust*, *satiety*, the sensation producing the desire to *defecate* or *urinate*, and the sensation of *itching* and *burning* of the skin—all these are considered as common sensations.

Special sensations are those by which the mind perceives occurrences in the external world, as, for instance, *sights*, *sounds*, the *character*, *size*, *form*, and *consistency* of various objects, etc.

These special sensations we perceive through the medium of specially constructed organs, which are called the organs of special sense, as, for instance, the eye, the ear, etc. We distinguish five special senses: touch, smell, taste, hearing, and sight.

The Special Sense of Touch.

By the contact of the skin and certain portions of the mucous membrane with various objects, certain sensations are produced, which are described as feeling.

These sensations may be of two kinds—viz., the sensation of *touch*, or the *tactile* sense, and the sensation of *thermal* conditions, or *temperature sense*. Through the former we perceive mechanical irritations of the skin, the character, form, and size of objects coming in contact with the skin, and by it we can localize the irritation. Through the temperature sense we perceive whether an object which touches the body is warmer or colder than the skin.

The tactile and the temperature senses are distributed all over the skin, and extend over certain parts of the mucous membrane—viz., over that of the lips, the tongue, the buccal cavity, and the nose; the tactile and temperature senses are restricted to these regions. Mechanical or thermal irritation of internal organs produces painful sensations, but not the sensation of touch or temperature.

The apparatus and mechanism through which we perceive the sensations of touch and temperature are the peripheral terminals of the sensory nerves of the skin, and of the mucous membrane of the regions mentioned.

The sensory nerves of the skin terminate in the subcutaneous cellular layer, in the cutis vera, and in the stratum mucosum of the epidermis.

The following peripheral terminations of the nerves of the skin are known as:

1. The end-bulbs of *Krause*.
2. The tactile corpuscles.
3. The Pacinian corpuscles.
4. Tactile cells.
5. Termination of fibrillæ.

1. The *end-bulbs of Krause* are minute, oblong, rounded bodies, consisting of a fine capsule which is filled with a

homogeneous substance and contains the axis-cylinder of a nerve-fibre; this terminates in a button-shaped expansion or in a spiral-shaped plexus.

End-bulbs of Krause are contained in the mucous membrane of the lips, tongue, nose, also in the conjunctiva; in the skin they are contained in the upper layers of the corium, or cutis vera, and in the papillæ.

2. The *tactile corpuscles* are contained principally in the papillæ of the skin of the soles of the feet and the palms of the hands. The tactile corpuscles are oblong, egg-shaped bodies which fill the papillæ; they consist of a connective-tissue capsule traversed by delicate, imperfect septa; the axis-cylinder of a nerve-fibre enters the capsule and divides into several delicate branches, which pursue a spiral course and terminate near the periphery of the capsule in fine, bulbous expansions.

Tactile corpuscles are found only in the papillæ of the skin of those regions which are most sensitive.

3. The *Pacinian corpuscles* are large, egg-shaped bodies, 1 to 4 millimetres in length, consisting of a number of connective-tissue lamellæ which enclose a space which is lined by a single layer of nucleated endothelial cells and is filled with a homogeneous transparent substance.

The axis-cylinder of a single nerve-fibre enters this space and terminates near the periphery in a rounded knob. Sometimes the fibres bifurcate. Such Pacinian corpuscles are found in the subcutaneous cellular tissue of the skin of the soles of the feet and palms of the hands; they are also found on the terminations of the sensory nerves of the joints. On account of their deep locations these corpuscles cannot be considered as organs of touch, but are probably the organs by which we perceive the sensations of tension and motion.

4. The *tactile cells* are epithelial cells in which, or between which, the primitive fibrillæ of a nerve-fibre terminate. This form of nerve-termination is found in

certain parts of the skin and mucous membrane and in the anterior epithelium of the cornea.

As I have stated before, through these peripheral nerve-termini we perceive the sensation of touch; we are able to localize the touching object and to distinguish its character and form: furthermore, we are enabled to distinguish thermal changes.

An important question which here arises is whether the organs for the sensation of touch and for temperature sensation are the same, or whether special nerves or special peripheral nerve-terminations exist for each of the two sensations. Certain pathological observations, and the fact that the two sensations are unequally distributed over the skin, tend to sustain the latter view. It has also been observed in certain pathological lesions that the sense of touch is totally absent while the temperature sense still exists, and *vice versa.*

Abnormally strong irritation of the skin produces a painful sensation, and again the question arises whether this sensation is produced by the abnormal irritation of the touch and temperature sensory organs, or by the irritation of special sensory nerves.

We must accept the former theory as the more probable, because the irritation of other nerves or organs of special sense does not produce pain; also because the mechanical irritation of all organs which are supplied with sensory nerves produces pain, although these organs are not provided with the described peripheral terminal apparatus of the nerves of the skin. Pathological observations also sustain this theory. In analgesia—viz., loss of painful sensation—a part of the sense of touch and temperature may exist undisturbed. We also know that tactile and thermal impressions are conducted in different portions of the cord, from the general sensory impressions.

By the *temperature sense* of the skin we perceive the sensations of warmth and cold. We are therefore able to

determine the exact degree of warmth of an object with which we come in contact. Experiments have shown that the temperature sense is differently developed in the various regions; the tip of the tongue is probably the most sensitive location in this respect. Very high and very low temperatures produce pain and temporarily decrease the temperature sense.

The fact is peculiar that if two portions of the skin which have an unequal temperature come in contact, the sensation of cold is perceived first; as a rule, however, it may be said that that temperature is perceived first which diverges mostly from the temperature of the skin.

The touch and temperature senses are destroyed in those parts of the surface of the body where the skin is destroyed or removed.

The Special Sense of Taste.

The seat of this sense is the mucous membrane of the tongue, the soft palate, the uvula, and the tonsils. The sense of taste is the result of the irritation of the peripheral termini of the glosso-pharyngeal nerves, by which the impressions are conducted to a special centre in the brain. The trifacial nerve, through its lingual branch, is also said to conduct impressions of this kind. It is, however, very likely that this nerve receives its fibres which conduct these impressions, through its various communications, from the glosso-pharyngeal nerve.

The tongue, which is the principal seat of the sense of taste, is composed of extrinsic and intrinsic muscles, and is covered with mucous membrane which contains numerous minute glands and follicles. The mucous membrane of the tongue consists of a layer of connective tissue, called the *corium* or *mucosa*, from which are projected numerous cone-shaped elevations called the *papillæ;* these, like the whole corium, are covered with scaly, stratified epithelium.

The papillæ contain the delicate organs of the sense of

taste. We distinguish three kinds of such papillæ: the papillæ circumvallatæ, the papillæ fungiformes, and the papillæ filiformes; they all differ in structure and location.

The *circumvallate papillæ*, or *papillæ maximæ*, 8 to 12 in number, are arranged in two diverging rows. Each papilla consists of a cone-like projection from a depression in the mucous membrane in the back part of the dorsum of the tongue, near its base. The papilla is surrounded by a shallow depression; it is narrow at its base and wider at its free end. Projecting from its surface are numerous minor or secondary papillæ; the surface of the papilla is made smooth by the epithelium covering it.

The *fungiform papillæ* are found principally at the sides and tip of the tongue; they are more numerous than the former; they are rounded projections from the mucous membrane, are broader at their free end than at their attached base, and also present secondary papillæ; their surface is covered by a thin epithelial layer and has a dark-red color.

The *filiform papillæ* are distributed principally over the mid-portion of the dorsum of the tongue; they are smaller, cone shaped elevations, from the apices of which are projected fine, filiform processes or secondary papillæ.

Besides these three characteristic forms the mucous membrane also presents numerous *simple papillæ* which resemble those of the corium of the skin, and consist of a cone-like elevation which is covered with epithelium and contains in its interior a capillary network.

The *structure* of the papillæ of the tongue resembles that of the papillæ of the corium of the skin. They are elevations from the surface of the mucosa or the corium of the mucous membrane; they are covered with epithelial cells and contain capillaries and nerve-terminals; they differ in structure from the papillæ of the skin, in that they present secondary papillæ and in that the nerve-termini differ.

In the circumvallate papillæ and in the fungiform these

nerve-terminals are very abundant and consist of a plexus of large nerve-fibrillæ. The mode of nerve-termination in the filiform papillæ is not fully known.

In the epithelium covering the circumvallate and many of the fungiform papillæ are situated numerous peculiarly constructed bodies which are known as *taste-goblets* ; these are oblong, rounded bodies which are attached by one end to the corium of the mucous membrane, while the other end presents minute openings which open between the epithelial cells. Their walls are composed of two kinds of cells : the outer, or cortical layer, consists of elongated cells which are connected at their edges ; the inner layer consists of long, nucleated, spindle-shaped cells called the *gustatory cells.* The fibres of the glosso-pharyngeal nerve enter the taste-goblets at their base, terminating in them in a fine, fibrillar plexus, the fibres of which are, however, not connected with the taste-cells.

Through the sense of taste we differentiate between the various qualities of the sensation ; we perceive a sweet, sour, bitter, alkaline, or saline taste. The various portions of the tongue are unequally endowed with the sense of taste ; it is distributed only to the tip, the posterior part of the dorsum, and in part to the sides of the tongue. Again, the sense for distinguishing between different qualities of taste is not the same in all parts of the tongue. Thus we find that a bitter taste is principally distinguished by the back part of the dorsum, and sour and sweet tastes are recognized by the tip of the tongue.

The many variations of taste are due to the fact that the taste sensations are accompanied, first, by the sensation of touch, produced by its coming in contact with the organs of touch ; second, by those substances which we taste ; and third, by the sensation of smell produced by the tasting of odoriferous substances.

LECTURE XLVII.

THE SENSES AND THE SENSORY ORGANS (*continued*).

The Sense of Smell.

THROUGH the sense of smell the mind obtains knowledge of the quality of the various odors emanating from odoriferous substances. The sensation is caused by the stimulation of the terminals of the olfactory nerves. The impression is conducted by the olfactory nerves, which are the nerves of the special sense of smell, to the centre in the brain which is thus stimulated, and the activity of which causes the sensation of smell.

The mucous membrane of the upper third of the septum of the nose, of the superior turbinated bones, upper part of the middle turbinated bones, and the upper part of the nasal cavity beneath the cribriform plate of the ethmoid, is the seat of the sense of smell. The mucous membrane covering this region of the nasal cavity is termed the *olfactory membrane.* It is covered with non-ciliated columnar epithelial cells, and scattered between these are found peculiar fusiform cells which are called the *olfactory cells;* they have projections penetrating into the depth, and it is supposed that these are connected with the terminals of the fibres of the olfactory nerves.

An essential condition for the sensation of smell is that we inspire air through the nose. If we breathe through the mouth or stop breathing we do not smell. The sensation of smell is also stronger during inspiration than during expiration. The sense of smell is exceedingly acute; through it we are able to recognize substances in smaller quantities than by means of any other sense.

Exactly how it is that we recognize so many odors has not been fully explained. It is not likely that there are special fibres and termini for each of the various odors. It is more likely that the stimulation of the peripheral termini is due to a chemical influence by the particles of odoriferous gases, and that this chemical influence varies with the different substances, thus causing the various sensations of smell.

The Sense of Hearing.

Through the sense of hearing the mind is able to perceive the various sounds and their character. The sensation of sound is produced through the irritation of the peripheral terminals of the auditory nerve in the inner ear by the sound-waves. The auditory nerve possesses the specific property of conducting to centres in the brain impulses which result in the sensation of hearing. The special centres are located in the cerebral psycho-sensorial area of the cortex. Direct stimulation of the fibres of the auditory nerve does not produce sensations of hearing; it is the nerve-terminations in the middle ear which are stimulated by sound. Destruction of the middle ear causes total deafness on the respective side.

The Organs of Hearing.—The ear consists of three principal parts—viz., the external ear, the middle ear or tympanum, and the internal ear or labyrinth.

The *external ear* consists of the auricle or pinna and of the meatus.

The *auricle* or *pinna* is the outer ear; it is a concave, oval organ attached to the sides of the head; it serves to collect the vibrations of the air by which sound is produced.

The organ is directed with the convexity of its border backward and with its concavity forward; at its bottom the auricle communicates with the auditory canal. The auricle is composed of a thin plate of yellow fibro-cartilage

and of ligaments and muscles; its surfaces are covered with skin, which outside is continuous with that of the head, and inside is continuous with the skin lining the auditory canal.

The *meatus auditorius externus*, or the *auditory canal*, is a little over an inch long, and begins by a funnel-shaped expansion at the deepest portion, or concha, of the concavity of the auricle; it passes inward and forward, and is bounded internally by the membrana tympani. The auditory canal consists in its external third of cartilaginous, and in its posterior or inner two-thirds of osseous walls. The canal is constricted at its mid-portion and expanded at its ends; the inner opening is covered with the membrana tympani, which is a round membrane composed of elastic fibres, is about one-tenth of a millimetre thick, and is stretched over the internal opening of the canal. In its centre the membrana tympani presents a funnel-shaped indentation, which is produced by the connection of the handle of the malleus with the internal surface of the membrane.

The *middle ear*, or *tympanum*, is an irregular-shaped cavity contained in the petrous portion of the temporal bone; its *outer* wall is formed by the membrana tympani, its *roof* and *floor* by osseous lamellæ. In its lower portion the tympanum communicates with the pharyngeal cavity by the *Eustachian tube;* its inner walls are formed by the bony walls of the labyrinth. In the interior of the tympanum are contained the three ossicles, called, from their shape, the *malleus*, *incus*, and *stapes*, which are connected with the membrana tympani and the labyrinth. The handle of the malleus is attached to the inner surface of the membrana tympani; its head is connected by a joint with the incus. The malleus has, at the junction of its head with the handle, two processes. The *long process*, called the *processus foliaceus*, is directed forward and is attached to the anterior wall of the tympanic cavity; the other,

the *short process*, is directed toward the upper border of the tympanic membrane ; the *head* is directed upward, extending over the upper edge of the tympanic membrane.

The *incus* resembles somewhat a molar tooth with two roots. The surface of the body of the incus, which would correspond with the masticating surface of the crown of the molar tooth, articulates with the head of the malleus. Projecting from the body are two processes resembling the roots of a tooth ; the shorter of the two is projected horizontally backward and is attached to the posterior wall of the tympanic cavity ; the longer process is directed downward, parallel with the handle of the malleus ; its lower part is bent a little inward and terminates in a small button-shaped expansion called the *os orbiculare*, which articulates with the little head of the stapes. The foot portion of the stapes is attached to the membrane which covers the *fenestra ovalis* in the inner walls of the tympanic cavity.

The ossicles in the tympanum are connected with each other and with the walls of the tympanum by fine ligaments, and are moved by two small muscles—viz., the *tensor tympani* and the *stapedius*. The former, by its contraction, acts upon the tympanic membrane ; the latter is attached to the head of the malleus, and by its contractions draws it backward.

The cavity of the tympanum is lined with mucous membrane which is continuous with that lining the pharynx, through the Eustachian tube. Inward the mucous membrane of the tympanum is continuous with that which lines the mastoid cells in the mastoid portion of the temporal bone. The mucous membrane covers the walls of the tympanum, and the ossicles, membranes, and muscles in the same ; it is covered with ciliated epithelial cells. The cavity of the tympanum is filled with air through the Eustachian tube.

3. The *internal ear*, or *labyrinth*, consists of the osseous and the membranous labyrinth.

(*a*) The *osseous* labyrinth is a complex excavation in the interior of the petrous portion of the temporal bone, internal to the tympanum. The cavity of the labyrinth communicates at its anterior wall, by two foramina, with the cavity of the tympanum. The two foramina—viz., the *fenestra ovalis* and the *fenestra rotunda*—are closed by membranes; to that covering the latter foramen is attached the foot-plate of the stapes, or stirrup. The osseous labyrinth consists of three parts—viz., the vestibule, the semicircular canals, and the cochlea.

The *vestibule* is the central portion of the cavity of the internal ear.

The *semicircular canals* are three semicircular excavations in the substance of the bone, posterior to the central cavity, or vestibule, with which the canal communicates. According to the direction in which these canals penetrate the substance of the bone, they are called the *superior*, the *anterior*, and the *posterior* semicircular canal.

The *cochlea* is an excavation in the bone anterior to the vestibule; the cochlea resembles the interior of the shell of a common snail.

(*b*) The *membranous labyrinth* is a closed membranous canal which is filled with a fluid, the *endolymph*. The membranous labyrinth is attached to the walls of the excavations of the three portions of the bony labyrinth To the walls of the membranous labyrinth are distributed the terminations of the fibres of the auditory nerve. External to the walls of the membranous labyrinth is a collection of fluid, the *perilymph*.

The *auditory nerve* enters the cavity of the internal ear through the meatus auditorius internus. Entering the labyrinth or internal ear, it divides into two branches—one which is distributed to the vestibule and semicircular canals; the other is distributed to the cochlea. The exact

mode in which the fibres of the auditory nerve terminate is not known.

The *function* of the complicated auditory apparatus is to conduct sound to the terminals of the auditory nerve, which are thus stimulated. For this purpose alone, however, the auditory apparatus would not need to be as complicated as it is. The complex structure of the organ has for its object the perfection of the sonorous vibrations, and maintaining as much as possible the strength and character of the vibrations.

The vibrations are conducted to the termini of the auditory nerve by three media—viz., by the air. by the solid portions of the auditory apparatus, and by the liquid in the internal ear.

The function of the auricles is to collect the vibrations. These are conducted by the air through the auditory canal to the membrana tympani; the vibrations are transmitted to the membrane which covers the fenestra ovalis through the medium of the chain of ossicles in the middle ear; the vibrations of this membrane are transmitted by the fluid in the labyrinth to the terminals of the auditory nerve.

This fully explains the functions of the membrana tympani, of the ossicles in the middle ear, of the membrane covering the fenestra ovalis, and of the fluid in the labyrinth.

The function of the Eustachian tube is to maintain an equal density between the air in the tympanum and the external air. It thus prevents the effects of an increased tension of the tympanic membrane.

The membrana tympani and the whole auditory apparatus are so constructed that the sonorous vibrations, which differ in number and strength in the various sounds, are conducted to the auditory nerve in a nearly even strength —which tends to explain why the mind perceives the various sounds as such.

The time is too limited to say anything on the subject of acoustics in connection with the sense of hearing. I have therefore confined myself purely to the physiology of hearing.

LECTURE XLVIII.

THE SENSES AND THE SENSORY ORGANS (*continued*).

The Sense of Sight.

THE organ of the sense of sight is the eye. The nerve for the special sense of sight is the optic; the terminal expansion of this nerve into the retina is the organ by which sight is perceived. Light is conducted to the retina by the refracting media of the eye—viz., the cornea, the aqueous humor, the crystalline lens, and the vitreous humor. The eyeball is contained in the orbit, in which cavity it is well protected against external injury; in the orbit the eyeball is embedded, for further protection, in a mass of adipose tissue.

The capsule of *Tenon*, or *tunica vaginalis oculi*, is a serous membrane which, in the form of a thin sac, surrounds the eyeball, separating it from the mass of adipose tissue in which it is embedded; this serous membrane serves to facilitate the motions of the eyeball.

The eyeball measures about one inch in its transverse and nine-tenths of an inch in its antero-posterior diameter.

If we examine the eyeball we find that it is a globe formed by the placing together of portions of two spheres of different sizes. The anterior sixth of the globe is a portion of a smaller sphere, while the posterior portion, including the remaining five-sixths, is composed of a segment of a larger sphere.

The eyeball is composed of several tunics and of refracting media.

1. The *tunics* of the eye are:
    (*a*) The sclerotic and the cornea.
    (*b*) The choroid, iris, and ciliary processes.
    (*c*) The retina.
2. The *refracting* media are:
    (*a*) The aqueous humor.
    (*b*) The crystalline lens and its capsule.
    (*c*) The vitreous humor.

(*a*) The *sclerotic* is a dense, firm, fibrous, opaque membrane which forms the external tunic of the posterior five-sixths of the eyeball and serves to maintain its form. It is thick behind, and thin and tapering toward its anterior borders. The outer surface of the sclerotic is smooth, white, and glistening, and partly covered by the conjunctiva; to it are attached the recti and oblique muscles; its inner surface is brown, owing to pigmentation. The sclerotic is pierced posteriorly and a little internal to the middle line by the optic nerve, the sheath of which becomes continuous with the sclerotic at the point where the optic nerve enters it; it is also pierced by numerous fine openings which serve to transmit the fibres of the optic nerve. In front the sclerotic becomes continuous with the cornea, the border of which is overlapped by that of the sclerotic.

The *cornea* is the tunic of the anterior sixth of the eyeball; it is almost circular in its outline and has a convex anterior surface. The degree of convexity varies at different ages; it is more convex in youth than in old age; the convexity also varies in different individuals. The cornea is very dense, of an even thickness, and transparent. Examined under the microscope it will be found that the cornea consists of four layers, which may be described as follows:

The *first* or *outer* layer consists of several layers of epithelial cells; the outer ones are scaly, flattened cells, the middle many-sided, and the deepest columnar cells.

The *second* layer constitutes the *cornea proper;* it con-

sists of a perfectly transparent, very dense, fibrous membrane, which is composed of many layers of connective-tissue fibres which are continuous with those of the sclerotic. Between the layers of connective tissue is a cement holding them together. In it are seen open spaces —the *corneal spaces*—each of which is nearly filled with a stellate cell, the *corneal capsule.*

The *third* layer is called the *posterior elastic lamina ;* it is a firm, elastic, and exceedingly thin, transparent, homogeneous membrane which covers the cornea behind. At the border the membrane breaks into fibres which are connected with the sclerotic and the choroid coat ; some of them are continued into the iris.

The *fourth* layer consists of a single layer of flattened, polygonal, transparent cells. This layer forms the anterior part of the lining of the anterior chamber of the eyeball. The cornea is a *non vascular* structure, but is freely supplied with nerve-fibres from the ciliary nerves.

(*b*) The second tunic of the eyeball is formed by the *choroid coat* behind, by the *iris* in front, and by the *ciliary processes* at the point where the cornea and sclerotic join.

The *choroid coat* is a thin, very vascular membrane which invests the eyeball beneath the sclerotic. Posteriorly and a little internal to the central point it is pierced by the optic nerve. Anteriorly it extends as far as the cornea, where it is connected with the iris by a number of folds called the *ciliary processes.*

The choroid consists of a network of veins and arterioles from the short ciliary arteries. From these, in the deeper parts, a delicate capillary network is formed, which is supported by a fine stroma and contains in its meshes star-shaped pigment-cells. On the inner surface of the choroid there is a thin, structureless membrane which separates it from the pigmentary layer of the retina.

The *iris* is a thin, circular membrane which is suspended

in the aqueous humor, behind the cornea and in front of the crystalline lens. The iris is contractile and presents, a little internal to its centre, an opening—the *pupil.* By its border the iris is connected with the choroid; external to this is the ciliary muscle, which connects the iris with the cornea and with the sclerotic. The anterior surface of the iris is of different colors in different individuals, hence the name iris (a rainbow). The posterior surface is covered by a dark pigment and has a deep purple color. The iris consists of the following structures:

1. The *stroma.* This is composed of fine bundles of fibrous tissue which radiate toward the periphery. Some of them are arranged circularly at the circumference. These fibres form an interlacing network containing blood-vessels and nerves and a number of branching cells. The latter contain pigment-granules in dark-eyed individuals, which are absent in light-colored or blue eyes.

2. A layer of many-sided *cells*, located in front.

3. *Involuntary muscular fibres.* These consist of radiating and circular fibres. The latter constitute the *sphincter* of the pupil; they are located in the posterior surface of the iris, around the opening of the pupil. The radiating fibres constitute the *dilator* of the pupil; they converge from the circumference of the iris to the margin of the pupil, where they blend with the circular fibres.

4. *Pigment.* This is found in the form of granules in the fine, polyhedral cells in the anterior or posterior surface of the iris. The quantity and location of the pigment decide the light or dark color of the eye.

The *ciliary muscle* is a ring of non-striated muscular fibres, consisting of circular and radiating fibres, which pass from the iris to the choroid. This muscle serves to accommodate the eye for the vision to near objects.

The iris is freely supplied with blood-vessels and nerves. In the fœtus the pupil is closed by a delicate vascular mem-

brane, the *membrana papillaris.* At about the eighth month of intrauterine life this begins to disappear.

(*c*) The third tunic of the eyeball is formed by the retina. The *retina* is a thin, delicate membrane which consists mainly of the peripheral expansion of the optic nerve, with which it is continuous at the central portion behind where the optic nerve penetrates the sclerotic and choroid. The outer or posterior surface of the retina is directed toward the inner surface of the choroid; the inner surface of the retina is directed toward the vitreous humor. In the centre of the internal surface of the retina is a rounded elevation which is called the *yellow spot of Sommering,* or the *macula lutea;* this has a central depression, the *fossa centralis.*

When examined under a microscope it will be found that the retina is an exceedingly complex structure, consisting of ten layers. Beginning at the outer one, these may be enumerated as follows:

1. The *pigmentary layer.* This is the external layer, and consists of a single layer of many-sided epithelial cells which are filled with pigment-granules.

2. *Jacob's membrane* consists of a layer of rods and cones, which have also been termed the *neuro-epithelium.* The *rods,* which in man are more numerous, are arranged with their long axes perpendicular to the surface, and consist of an outer and inner portion. The former presents delicate transverse and longitudinal striæ. The inner portion is granular and communicates with the rod-granules in the outer nuclear layer.

The *cones* are flask-shaped bodies, which are directed with their tapering end toward the choroid, and with the broad end toward the membrana limitans externa. The cones, like the rods, are made up of two portions, an outer and an inner. The outer presents a striation similar to that of the outer portion of the rods; the inner portion

of the cones is granular, expands, and is connected with the cone-granules of the outer nuclear layer.

3. The *membrana limitans externa* is an exceedingly delicate membrane separating the layer of cones and rods from the external granular layer.

4. The *external granular layer* consists of a mass of small, round, nucleated and bipolar cells, which are connected by their processes, through the membrana limitans externa, with the rods and cones of Jacob's membrane. Because of their connection with these elements they are called *rod-granules* and *cone-granules*. The granular cells are supported by a delicate connective-tissue stroma: this layer is also called the *outer nuclear layer*.

5. The *outer molecular layer* consists of small, granular cells and a dense network of fine nerve-fibrillæ.

6. The *internal granular layer* resembles in its structure the external granular layer. It consists, like this, of small, rounded, nucleated, granular bipolar cells; this structure is also called the *inner nuclear layer*.

7. The *inner molecular layer* resembles in structure the outer molecular layer, but is thicker.

8. The *vesicular layer* consists of large ganglion-cells which have one process, which passes into the fibrous layer and is probably continuous in this with a nerve-fibre.

9. The *fibrous layer* is composed of fibres from the optic nerve; these fibres pass through the various layers of the retina and terminate in this fibrous layer.

10. The *membrana limitans interna* is the inner layer of the retina, and is in contact with the membrane covering the vitreous humor. It is composed of fine connective-tissue network.

The various layers of the retina are held together and supported by a fine connective-tissue framework. Its fibres pass into the various layers, with the exception of the rod and cone layer. The external and internal mem-

brana limitans are also formed by the fibres of this stroma.

The blood-supply to the retina is by the *arteria centralis,* which is accompanied by a venule. It pierces the optic nerve at its centre, and divides into several branches which anastomose and radiate between the retina and the membrane covering the vitreous humor. After a short course between these they pass into the layers of the retina and break up into a capillary plexus. The retina extends forward as far as the ciliary muscle, and terminates there in a ragged edge termed the *ora serrata.*

The function of the retina, the structure of which shows it to be a delicate nervous membrane, is to receive images of external objects.

2. The *refracting media of the eye* are those structures which serve to refract rays of light and collect them upon the retina.

(*a*) *The Aqueous Humor.*—The aqueous humor is the fluid which fills the anterior and posterior chambers of the eyeball; it is alkaline in reaction and composed principally of water and sodium chloride.

The *anterior chamber* is the space bounded in front by the cornea, behind by the anterior surface of the iris. The *posterior chamber* is the space between the ciliary processes and the periphery of the iris. The anterior surface of the crystalline lens is in close contact with the posterior surface of the iris.

(*b*) *The Crystalline Lens.*—The crystalline lens is a transparent body situated in front of the vitreous body and behind the pupil; it is double convex, being more convex on its posterior than on its anterior surface. It measures about one-third of an inch in its transverse and one-quarter of an inch in its antero-posterior diameter. The crystalline lens consists of a number of concentric laminæ and a central nucleus. Each lamina consists of delicate, prismatic, parallel fibres. The lens is enclosed in a trans-

parent and highly elastic membrane which is called the *capsule* of the lens. The lens and its capsule are held in position by a thin, transparent membrane, the *suspensory ligament.*

(*c*) *The Vitreous Humor.*—The vitreous body is a jelly-like, transparent, albuminous substance which is enclosed in a delicate, transparent membrane, the *hyaloid.* The vitreous body is contained in and fills the concavity of the retina ; in front it is bounded by the convex posterior surface of the crystalline lens.

The structures which I have thus described are those which compose the eyeball. Requisite for the proper activity and use of the eye are a number of accessory structures—viz., the conjunctiva, the lachrymal apparatus, the eyelids, the eyelashes, and the muscles of the eye.

The *conjunctiva* is a thin membrane, covered with epithelial cells, which covers the inner surface of the eyelids and in front of the eyeballs. The conjunctiva, being mucous membrane, serves to moisten the surface of the eyeball with its secretion.

The *eyelids* are two thin folds which are placed in front of the eyeball; they are movable and serve to protect the eye by their closure. They are composed of integument, subcutaneous areolar tissue, muscular fibres, thin cartilaginous plates, and a conjunctival lining; the latter contains numerous *Meibomian glands*, the secretion of which prevents adhesion of the eyelids to the globe.

The *eyelashes* are rows of short, thick hairs attached to the free edges of the eyelids; they serve to prevent the access of foreign particles to the eye.

The *lachrymal apparatus*—consisting of the lachrymal glands, the lachrymal sac, and the nasal duct—serves to moisten the surface of the eyeball by secretion.

The *muscles* of the eyeball are the *external*, the *internal*, and the *superior rectus* and the *superior* and *inferior oblique* muscles. These muscles are voluntary, and by

their action produce such movements of the eyeball as are required for the proper viewing of an object.

The *optical apparatus* of the eye consists of the following structures:

1. The retina, which is the peripheral terminal expansion of the optic nerve. The nervous membrane is stimulated by the rays of light falling upon it; the impulse is transmitted by the optic nerve to the brain, causing the sensation of vision.

2. The *refracting media*, which serve to converge and to collect upon one point on the retina the rays of light which pass from every external body in all directions.

3. The *iris* is a contractile structure which controls the opening of the pupil for the purpose of regulating the quantity of light admitted into the eye.

4. The *ciliary muscle*, which regulates the crystalline lens so that objects can be seen at various distances.

The structure of the retina as a nervous membrane I have already described. Its special function is to receive light-impressions; the optic nerve itself cannot be stimulated by light.

The refracting media are placed in front of the retina for the purpose of collecting the rays of light upon one point of the retina and thus producing a distinct vision. If these media were absent the rays of light which pass from a luminiferous body in all directions would strike all points of the retina and produce the sensation of light in contradistinction from darkness, but would not produce a distinct vision.

The *cornea*, owing to its form and structure, may well be considered as an important refracting medium of the optical apparatus. First, since it is a transparent, solid substance, all rays of light are bent from their original course in passing through it from a rarer medium; second, the outer surface of the cornea is convex, and all rays of

light falling upon a convex transparent surface are converged as they pass through the medium.

The use of the *aqueous humor*, which fills the anterior and posterior chamber, is probably the serving as a medium for the movements of the iris. The use of the aqueous humor as a refracting medium is not fully explained.

The most important refracting medium of the optical apparatus is the *crystalline lens;* its effectiveness as a refracting medium is explained by its form and structure. The uses of the vitreous body are principally to fill the eyeball and to maintain the distance of the lens from the retina.

The manner in which images of objects are thrown upon the retina is governed by the physical laws of the refraction of rays of light. As you are familiar with these laws, and also with the shape and consistency and position of the various refracting media of the optical apparatus, you do not require a detailed description of this subject. I will only say that the distinctness of the image formed upon the retina depends upon the exact focussing upon the retina of the rays emitted from a luminiferous body. The optical apparatus of the eye is so constructed as to be able to bring to a perfect focus upon the retina the rays of light emitted from objects at various distances. This property is described as the *accommodation* of the eye.

The *focal distance* is the distance between the surface of the lens, through which the rays have been transmitted, and the *focus*—viz., the point at which the rays are collected. The length of the focal distance depends upon the convexity of the lens and upon the distance at which the object is placed in front of the lens.

The focal distance increases as the distance of the object from the lens decreases, and *vice versa*. The focal distance increases with the convexity and density of the lens, and *vice versa*.

The optical apparatus, in order to be able to adapt itself to the vision of objects at different distances, must be pro-

vided with an appliance by which either the convexity and density of the crystalline lens and of the cornea are altered, or by which the distance between the retina and the lens can be changed ; in fact, the power of accommodation of the eye has received various explanations.

Helmholtz's theory as to the cause of the accommodation of the eye is now almost universally adopted. It is believed that the adaptation of the eye for objects at different distances is caused by a change in the convexity of the anterior surface of the lens ; for near objects it becomes more convex, and *vice versa*.

The power to change the convexity of the surface of the lens is not an inherent property. The changes are caused by the action of the ciliary muscle ; the contraction of this increases the tension of the suspensory ligament, and so somewhat flattens and decreases the convexity of the lens. Relaxation of the ciliary muscle has the reverse effect.

The focussing of rays of light is also regulated to some extent by the central opening of the iris—viz., the pupil. In viewing near objects the pupil contracts, and *vice versa*.

The *contraction* and *dilatation* of the pupil under various circumstances may be enumerated as follows:

1. It *contracts*—
   (*a*) When the eye is exposed to bright light.
   (*b*) When viewing near objects.
   (*c*) When the eyes converge to look at near objects.
   (*d*) After local administration of eserine.
   (*e*) After internal administration of opium, aconite, and in the first stages of alcohol and chloroform poisoning.
2. It *dilates*—
   (*a*) When the eye is exposed to dim light.
   (*b*) When viewing distant objects.
   (*c*) After local or internal administration of atropine or similar alkaloids.

(*d*) In the latter stages of opium, chloroform, and alcohol poisoning.

(*e*) In paralysis of the third nerve.

The defects of the optical apparatus may exist in the refracting media or in the accommodation power. The visual disturbances produced by these defects are : 1. Those produced by defects in the refractive media—viz., myopia, hypermetropia, and astigmatism. 2. The defect of disturbance produced by loss or decrease of the accommodation power is known as *presbyopia*—the far-sightedness of old people.

Myopia, or short-sightedness, is caused by the fact that the eyeball is too long antero-posteriorly, and that the distance from the lens to the retina is too great. In this condition the lens is probably more convex ; the result is that objects are focussed in front of the retina ; this defect is corrected by concave glasses.

Hypermetropia, or long-sight, is due to the reverse defects. In this condition objects are focussed behind the retina ; the defect is corrected by convex glasses.

Astigmatism as a defect is due to a greater curvature of the eye in one meridian than in others ; the result is that various rays are not equally focussed. The condition is obviated by cylindrical glasses.

The normal, or *emmotropic*, eye is so arranged that parallel rays are brought to a focus upon the retina without any effort at accommodation.

QUESTIONS AND EXERCISES.

SUBJECT.—*The Special Senses.*
Lectures XLVI. to XLVIII. inclusive.

730. Name the special senses.

731. Distinguish between special and general sensation.

732. Name the various forms of peripheral terminations of the sensory nerves of the skin and mucous membrane.

733. Which is the nerve of the special sense of taste ?

734. Describe the papillæ of the tongue.

735. Which is the nerve of the special sense of smell ?

736. Which is the nerve of the special sense of hearing ?

737. Give a short description of (*a*) the external, (*b*) the middle, (*c*) the internal ear.

738. Name the ossicles of the ear.

739. What is the Eustachian tube ?

740. Explain how the sensation of hearing is produced.

741. Name the nerve of the special sense of sight.

742. Name the tunics of the eye.

743. Name the refractive media of the eye.

744. What is the retina ?

745. What is the conjunctiva ?

746. Name the muscles of the eyeball.

747. Name the essential structures of the optical apparatus of the eye.

748. What do you understand by accommodation ?

749. What is the pupil ?

750. What causes dilatation and contraction of the pupil ?

751. How is the sensation of sight produced ?

752. Explain the following terms : emmetropia ; hypermetropia ; myopia ; presbyopia ; astigmatism.

LECTURE XLIX.

REPRODUCTION—GROWTH—DEVELOPMENT—THE MALE AND THE FEMALE SEXUAL PRODUCTS AND ORGANS.

THE functions of reproduction have for their object the preservation of the species. In man this process is the result of the union of the male and female sexual products; this takes place in the female sexual organs.

The union is preceded by a development of the sexual product. Reproduction is a process of growth and development.

The female sexual products are the ovi; the male sexual products, the spermatozoa. The human ovum is a typical cell; it is spherical, about $\frac{1}{240}$ to $\frac{1}{120}$ of an inch in diameter, and consists of a cell-wall, a cell-contents, a nucleus, and a nucleolus.

The cell-wall is transparent and is termed the *zona pellucida* or *vitelline membrane.* The cell-body filling the limiting membrane is called the *yolk* or *vitellus.*

The nucleus is termed the *germinal vesicle*, and the nucleolus contained within this is the *macula germinativa*, or *vitelline spot*, or *germinal spot.*

The zona pellucida is, as I have stated before, a transparent, colorless membrane. The yolk consists of a granular protoplasm contained in the meshes of a delicate reticulum. The germinal vesicle is contained nearly in the centre of the yolk, and consists of a delicate, transparent limiting membrane containing a clear substance with few granules. The germinal spot is contained near that portion of the periphery of the germinal vesicle which is nearest to the periphery of the ovum.

The ovi are developed and contained in the ovaries.

The *ovaries* are two oval-shaped bodies, situated, one on each side of the uterus, in the broad ligament and below the Fallopian tubes. An ovary consists of a serous covering, a peculiar soft, vascular stroma, and in the meshes of this a number of small vesicular bodies called the ovi-sacs or Graafian follicles. The serous covering of the ovaries is covered with a single layer of columnar epithelial cells which is termed the *germinal epithelium.*

The *Graafian follicles* are round and of various sizes; they consist of an external fibrous vascular coat, and an internal coat, which is lined by a layer of cells, termed the *membrana granulosa.* The vesicle is filled with a transparent albuminous fluid in which is suspended the ovum.

The formation of the Graafian vesicles and of the ovi commences before birth; their development and maturation continue from puberty until the menopause.

The ovi are formed from the cells of the germinal epithelium; these enlarge and become involuted. Small depressions containing these cells form on the surface of the ovary and finally become encapsulated. The walls of the Graafian vesicles develop from processes of the stroma. The Graafian follicles are small before puberty. At that period the ovaries enlarge, become more vascular, and the Graafian follicles enlarge and approach the surface of the ovary. As they do so the cells of the membrana granulosa collect into a mass called the *discus proligerus;* in this the ovum becomes embedded. As the Graafian vesicles mature and approach the surface of the ovary they burst, and the fluid and the ovum pass into the Fallopian tubes or oviducts.

The *Fallopian tubes,* or *oviducts,* are two tubular ducts, one on each side, situated in the upper border of the broad ligaments, and serve to conduct the ovi to the uterus. Each Fallopian tube consists of a fimbriated extremity, a dilated portion, and the isthmus or constricted portion.

The tube consists of an external serous, a middle muscular coat consisting of longitudinal and circular non-striated fibres, and an inner mucous coat lined with columnar ciliated cells.

The *uterus* is the organ of gestation, and is contained, like the ovaries and Fallopian tubes, in the pelvic cavity. It is the organ which receives the fecundated ovum, supporting the ovum during the development of the fœtus. In the normal condition the uterus is pear-shaped and consists of a body, the fundus, and of a neck or cervix. The external opening of the cervix opens into the vagina. The uterus is placed between the bladder in front and the rectum behind, and is held in position by ligaments.

The cavity is triangular. At each of the superior angles is the opening of the Fallopian tube. The lower angle has the opening into the neck of the uterus; this is called the *ostium uteri internum.*

The uterus is composed of an external serous, a middle muscular, and an internal mucous coat.

The *muscular coat* forms the main mass of the organ, and consists of non-striated fibres which are disposed in an external longitudinal and an internal circular layer.

The *mucous coat* consists of columnar ciliated cells and presents the openings of numerous tubular glands, the *uterine* glands. The organ is freely supplied with blood-vessels and nerves.

The *vagina* is the channel which extends from the uterus to the *vulva*, the external opening of the genital tract.

In the human female maturation and expulsion of the ovum occur once in every lunar month. During the development of the Graafian vesicle the uterine mucous membrane undergoes a development preparatory for the reception of the impregnated ovum. The developed mucous membrane is termed the *nidus*, or *decidua menstrualis.* If the ovum is impregnated this membrane serves to retain the ovum in the uterine cavity, and later on constitutes

the *decidua vera.* If no impregnation has taken place the *decidua menstrualis* undergoes a destructive process and is eliminated, a process which is accompanied by a hemorrhage from the surface of the uterine cavity, which constitutes the menstrual flow.

Menstruation is, therefore, the result of the destruction and shedding of the nidus or decidua menstrualis. The menstrual flow consists of blood, shreds of the decidua menstrualis, epithelium, and mucus ; it has a dark color, a peculiar odor, and does not readily coagulate. Menstruation generally occurs once every lunar month ; the intervals are, however, longer or shorter in different individuals. The flow lasts from three to six days, and is often preceded by a heavy feeling in the pelvis and by pains in the loins and limbs.

The menstrual period generally begins at the age of fourteen or fifteen years. The time of the first appearance varies, however, in different climates, and is also influenced by the mode of life and the habits of the individual. The first appearance of the menstruation is the principal sign of the commencement of puberty. The flow recurs at more or less regular intervals during the whole fruitful period of the life of the woman, which ends generally between the forty-fifth and fiftieth year. The menstrual flow is generally absent during pregnancy and during the time of nursing ; cases where the flow occurs during these periods are not rare.

Observation and clinical facts tend to show that menstruation occurs at the period of the discharge of an ovum, and that this discharge occurs just before the beginning of the menstrual flow. It must, therefore, be supposed that conception occurs just before the menstrual flow, not immediately after it ; the fecundated ovum is consequently that which is discharged prior to the first absent menstruation.

The fact that extirpation of both ovaries causes a cessa-

tion of the menstruation tends to show that there is a connection between the discharge of the ovum and menstruation, although cases are not rare in which menstruation has been absent for several months and still conception took place ; this shows that menstruation does not depend upon the discharge of the ova.

The Graafian vesicle, after its rupture and after the discharge of the ovum, undergoes certain changes which result in the formation of a yellowish body called the *corpus luteum.* This is a rounded, solid mass of a yellowish color, and consists of a number of lobules and a central cavity which is filled with a whitish, trabeculated mass.

After rupture the walls of the Graafian vesicle become thickened by the development of a fleshy-looking substance on the inner layer of the walls. This is then thrown into folds or lobules by the contraction of the outer layer, leaving a central, stellate, cicatricial cavity. The yellowish color of the corpus luteum is produced by the increase of the cells of the membrana granulosa of the inner wall of the Graafian vesicle ; the central whitish, stellate mass is fibrin of the blood resulting from the rupture of the vesicle.

If no impregnation of the ovum takes place, only a small amount of yellow mass is developed ; the corpus luteum assumes the size of about three-quarters of an inch, then contracts, and finally disappears at about the second month.

The corpus luteum formed under these circumstances is termed the *corpus luteum spurium.* If impregnation of the ovum does take place the yellow substance continues to develop throughout the whole period of pregnancy, resulting in the production of the large corpus luteum of pregnancy, called the *corpus luteum verum.*

The Semen of the Male.

The semen of the male is the fluid secreted by the testes, the vesiculæ seminales, the prostate gland, and Cowper's

glands, which structures must be considered as the male sexual organs.

The *testes* consist of a body, the epididymis, and the vas deferens. The *body* consists of the *seminal tubules;* these are convoluted tubules composed of a basement membrane lined with several layers of secreting epithelial cells called *seminal cells;* these cells are disposed in two layers—an outer or peripheral, and a central or inner layer. The latter are the active cells from which the spermatozoa are formed; they are called the *spermatoblasts.* The seminal tubules are held together by trabeculæ. The whole organ is surrounded by a tough, fibrous membrane termed the *tunica albuginea;* external to this is a serous covering, the *tunica vaginalis.*

The *epididymis* is located at the back part of the testicle; it is a very convoluted tube, which, unwound, is about twenty feet long. It is lined with ciliated columnar epithelium, and constitutes the lower portion of the duct of the testicle.

The *vas deferens* is the duct proper of the testicle; it is about two feet long, and begins at the lower and back part of the epididymis, with which it is continuous; it is composed of a fibrous coat and a mucous lining covered with columnar epithelium; between the fibrous and the mucous coats is a layer of plain muscular fibres. Its diameter is smaller than that of the epididymis; it pursues a very tortuous course upward along the posterior part of the testicle and inner side of the epididymis, through the spermatic canal, to the internal abdominal ring; it then descends into the pelvic cavity to the side of the bladder, on which it passes downward to the base and to the urethra. At the base of the prostate gland it unites with the duct of the vesicula seminalis, forming one common duct, the *ejaculatory duct*, which opens into the prostatic portion of the urethra.

The *vesiculæ seminales* are two convoluted pouches

placed at the base of the bladder external to the vasa deferentia. They serve as reservoirs for the seminal fluid secreted in the testes; they also secrete a fluid which is mixed with the semen. Their ducts unite with those of the vasa deferentia.

The *prostate* gland is placed at the neck of the bladder, surrounding the posterior end of the urethra. The organ is composed of a dense fibrous capsule of muscular fibres and of glandular tissue. The latter consists of follicular expansions which communicate with channels; these join and form a number of excretory ducts which open into the prostatic portion of the urethra. The secreting portion of the gland is lined with columnar epithelium. *Cowper's glands* are two small glandular bodies situated beneath the mucous membrane of the membranous portion of the urethra; they eliminate their secretion by two long ducts which open into the bulbous portion of the urethra.

The testes are freely supplied with blood-vessels and nerves; these and the ducts of the testes are contained in the *spermatic cord.*

The secretion of the structures just described constitutes the *semen;* this is composed of the liquor seminis and of the spermatozoa and of detached epithelial cells.

The *liquor seminis* consists of an albuminous fluid.

The *spermatozoa* are microscopical, elongated organisms consisting of a pointed, elongated head, a long, filiform, rounded body, and a long, thin, slender tail. In the living spermatozoa this tail is in a constant wavy lateral motion; in man the tail is longer than in any other mammalia.

The seminal fluid is secreted continuously and is stored in the vesiculæ seminales; from these it is discharged during coition or spontaneously into the bladder. The secretion of semen occurs very slowly, except under special excitement.

It is unknown exactly what ingredient makes the semen

capable of impregnating the female ovum, but the fact that the spermatozoa exist in the impregnating fluid of all animals tends to show that they are essential for the act of impregnation.

LECTURE L.

THE FECUNDATION OF THE OVUM, AND THE IMMEDIATE CHANGES TAKING PLACE IN THE OVUM AFTER ITS IMPREGNATION

The fecundation of the ovum is caused by the entrance of a single spermatozoon into it. This takes place either in the ovary (which explains the occurrence of abdominal pregnancies), or, as is generally the case, in the Fallopian tube. The spermatozoon passes to the tube by its own motion.

The ovum passes, in from two to three weeks, through the Fallopian tube, and once in the uterine cavity it is not again subject to impregnation.

The spermatozoa enter the Fallopian tube, and the one which first approaches the escaped ovule enters it with its head, while its filiform tail becomes detached and disappears. I have stated before that as the ovule matures its germinal vesicle approaches the surface of the ovule and undergoes certain changes, which always take place and are independent of the fecundation of the ovule. These changes are as follows: At about the time of maturation of the ovule a portion of the germinal vesicle is detached and pushed outward beneath the vitelline membrane; this constitutes the *first polar globule*. Then a second portion of the germinal vesicle is similarly detached and pushed outward; this is called the *second polar globule*. The remaining portion of the germinal vesicle passes back toward the centre of the vitellus and becomes a round, nuclear body called the *female protonucleus*. At the time of these changes there takes place a shrinking of the vitellus.

The head of the spermatozoon which enters the ovule passes toward the female protonucleus, becomes a rounded body, and constitutes the male protonucleus. This gradually approaches the female protonucleus and finally fuses with it into one mass. This constitutes the process of fecundation.

The first change after fecundation is that the germinal spot, or female protonucleus—that is, the nucleus formed by the fusion of the male with the female protonucleus—divides into two nuclei. This is followed by a division of the vitellus, so that as the result of this division two cells of an unequal size are formed; these are called the *vitelline spheres.* The smaller of the two is, for the sake of distinction, called the *hypoblastic cell;* the larger, or upper, the *epiblastic cell.* These then continue to divide and subdivide, until as the result of this continued cleavage a mulberry-shaped mass is formed, which is called the *blastoderm.* The division of the cell takes place by indirect division, mitosis or karyokinesis—a process which I have described in detail in a former lecture; the vitelline membrane takes no part in this division. This constitutes an investment of the impregnated ovum; another transparent albuminous investment forms around the ovule as it passes through the Fallopian tube.

As the blastoderm develops, its outermost cells—viz., those derived from the epiblastic cell or sphere—show a tendency to divide at a much more rapid rate than the cells of the inner layer—viz., those derived from the hypoblastic cell or sphere.

The epiblastic cells gradually form a layer around the hypoblastic cells, so that after a while we find the blastoderm to consist of a central or inner layer of cells from the hypoblast and of an outer layer of cells from the epiblast.

Owing to the slower rate of division, the hypoblastic cells are larger but fewer in number than those of the outer or epiblastic layer. The cells of the inner or hypoblastic layer

at this time become more granular. Gradually a fluid collects between these two layers of cells, separating them, except at the ends where they remain united.

The mass of cells within the vitelline membrane, consisting of the two layers just described, is called the *blastodermic membrane;* it consists at this period of two layers—viz., the *outer* or *epiblastic*, and the *inner* or *hypoblastic* layer; they are also called the *ectoderm* and the *endoderm*. Gradually a third layer develops between the two—the *mesoblastic layer* or *mesoderm*. It is believed that this is formed from cells of the epiblast and hypoblast; however, nothing definite is known about it.

The blastodermic membrane consists eventually of three layers—viz., the hypoblast or endoderm, the epiblast or ectoderm, and the mesoblast or mesoderm.

From these layers the various structures of the embryo are developed as follows:

1. From the *hypoblast*, *endoderm*, or *inner layer:* (*a*) The internal epithelium—viz., that of the alimentary canal, of the respiratory tract, and that of the glands opening into these. (*b*) The allantois.

2. From the *epiblast*, *ectoderm*, or *outer layer:* (*a*) The epidermis and all its involutions. (*b*) The nerve structures —viz., the brain, spinal cord, the nerves, etc.

3. From the *mesoblast*, *mesoderm*, or *middle layer:* All the other embryonal structures—viz., the vascular organs, the organs of locomotion, the connective tissues, the genito-urinary organs, etc.

The position in which the embryo is about to develop in the ovum is first seen in the blastoderm as a central rounded, opaque spot resulting from a congregation of cells at this place. This is termed the *area germinativa*, the first form of which is that of a round disc; gradually it becomes elongated and constricted at the centre, assuming a lady-finger shape. The central portion of this area becomes transparent and is called the *area pellucida*.

The next change is the appearance of a shallow groove, visible as a finer streak in the posterior part of the area pellucida. This is termed the *primitive trace* or the *primitive groove.* Simultaneously with these changes the already-described separation of the cells of the blastoderm into two layers—viz., the epiblast and the hypoblast—takes place, and, after the appearance of the primitive trace, the middle layer or mesoblast is formed. After these changes the development of the fœtal structures, known as the medullary groove, the laminæ dorsales, the notochord, and the protovertebræ, takes place.

The *medullary groove* is formed by the folding of cells of the epiblast. It begins in the anterior part of the area germinativa, and gradually extends over the whole length of the primitive tract. This folding of the cells results in the formation of a groove, the sides and bottom of which are formed by cells from the epiblast.

The space between the epiblast and the hypoblast is filled with the cells of the mesoblast. The epiblastic cells which form the sides of the groove develop into two lateral plates, called the *laminæ dorsales* or *medullary plates.* These finally come together at their free ends, thus forming a closed canal, called the *neural* or *medullary canal,* which is formed and lined by cells of the epiblastic layer alone.

The cells lining the neural canal develop into nerve-centres; those covering the canal develop into epidermis of the head and back. The cephalic extremity of the neural canal gradually dilates, and from it develops the brain, while from the remaining constricted portion the spinal cord develops.

At the bottom of the neural canal the cells of the epiblastic layer come together with those of the hypoblastic layer, so that the cells of the mesoblast between them become separated into two thick masses, which are arranged at the sides of the neural canal. The next change is that

a mass of the cells from the hypoblast becomes thickened and finally detached from its layer. This is termed the *notochord.* This is located at the bottom of the neural canal and between the epiblastic and the hypoblastic layers. These two layers at this period are no longer in contact, but separated from each other. The thickened masses from the mesoblastic layer which are located at the sides of the neural canal gradually become separated from the remainder of the mesoblastic layer, which is situated laterally to the protovertebra, and thus divides into two layers. One, which covers the hypoblast, is called the *splanchnopleura;* the other, which covers the epiblast, is called the *somatopleura.* From the former the muscular and other mesoblastic structures of the viscera are developed; from the latter the cutis vera and the skeletal muscles. The space between these two layers forms the pleuro-peritoneal cavity. The embryo, which has so far developed from the cells of that part of the blastodermic membrane which is known as the area germinativa, is at this period merely a straight structure. It now becomes more and more curved at its cephalic and caudal extremities, so that finally the blastodermic membrane becomes constricted at the point of the curvature of the extremities of the embryo. The blastodermic membrane thus assumes an hour-glass shape, the smaller globe or portion of which is formed by that part of the blastodermic membrane from which the embryo so far has developed, while the larger portion or globe is developed by the remainder of the blastodermic membrane. This larger portion is termed the *yolk-sac* or the *umbilical vesicle,* the interior of which communicates, at the point of constriction of the blastodermic membrane, with the interior of the smaller globe. This point of constriction is the place of the future umbilicus. The constriction gradually increases, so that the cavity of the yolk is divided into halves—one which constitutes the interior of the umbilical vesicle, and one which develops into the intestinal

cavity of the embryo. At the point of constriction there remains an opening, the *omphalo-mesenteric duct.*

The umbilical vesicle, at this period of the embryonic development, serves to supply nutrition for the embryo. The walls of the umbilical vesicle are formed by the epiblast and the hypoblast, with the inner layer of the divided mesoblast—viz., the splanchnopleura—between the two.

The function of the umbilical vesicle as an organ for the nutrition of the embryo ceases at about the sixth week. During this period two vessels, called the *omphalo-mesenteric* vessels, develop, which absorb the fluid contents of the vesicle. This dries up and becomes small, but remains visible until the fourth or fifth month of pregnancy. At about the sixth week a new fœtal structure is developed, called the *allantois*, and serves for the vascular connection between the embryo and the maternal uterine vessels. The allantois is a part of the chorion; this is one of the three membranes which invest the embryo during its development.

These three fœtal membranes are : the amnion, the chorion, and the decidua.

The *amnion* is the first of the fœtal membranes which is developed. It is formed from embryonal structures, and is the membrane which immediately surrounds the fœtus during the whole period of gestation.

The process of the formation of the amnion is as follows : At the point of constriction of the blastodermic membrane (viz., at the caudal and cephalic ends of the embryo) a fold of the somatopleura (viz., of the epiblast) and the parietal layer of the divided mesoblast becomes inflected and arches backward over the sides and back of the embryo, until finally the two folds meet and fuse over the dorsum of the embryo, which thus becomes totally invested by a bag which is composed of two layers—viz., an inner from the epiblast, and an outer from the parietal layer of the mesoblast at the point of fusion of the two

folds. The epiblastic layer of the amnion becomes reflected and lines the inner surface of the vitelline membrane constituting the chorion. That part of the amnion which directly covers the embryo is called the *true amnion*, while the reflected layer of the amnion is termed the *false amnion*. The space between the two is filled with a thickish fluid and communicates with the pleuro-peritoneal cavity—viz., with the space between the parietal and the visceral layers of the divided mesoblast.

The space between the true amnion and the embryo is called the *amniotic cavity*. It gradually becomes filled and expanded with a fluid called the *liquor amnii*. This is composed of water, salts, small amounts of albumin, and urea. This fluid steadily increases until about the fifth or sixth month of gestation. It serves to protect the embryo from external violence, and to afford an equal support for the development of the fœtus.

The *chorion* is the second of the fœtal membranes. It is also developed from fœtal structures, and is composed of the following parts: 1, the vitelline membrane; 2, the reflected portion of the amnion—viz., the false amnion; and 3, the allantois, a structure which develops between the two layers of the mesoblast.

As the chorion develops, fringe-like processes arise from the external surface. These are at first fibrous and cover the whole external surface; later on they become vascular and form villi, and develop only on that part of the external surface which is to form the fœtal portion of the placenta.

The *allantois* is a structure which develops from the hypoblast and visceral layer of the mesoblast—viz., the splanchnopleura; it arises from the caudal end of the body cavity of the fœtus as a hollow vesicle. This gradually expands between the walls of the pleuro-peritoneal cavity, and finally spreads over and unites with the internal surface of the false amnion—viz., the inner layer of the

chorion. Blood-vessels, termed the allantoic vessels, develop in the allantois, and from there minor branches pass into the fringe-like processes of the external surface of the chorion, which thereby become villi. The allantoic vessels are the channels through which the embryo receives its nutrition. They finally constitute the vessels of the umbilical cord.

The *decidua* is developed from the mucous membrane of the uterus. In my last lecture I stated that before the ovum reaches the uterine cavity the mucous membrane develops for reception and retention of the ovum in case it is fecundated, and that, if such is not the case, the developed uterine mucous membrane is shed with the menstrual flow. When the impregnated ovum reaches the uterine cavity it becomes completely embedded in folds of the mucous membrane. That portion of the membrane which surrounds the ovum is termed the *decidua reflexa*, while the portion upon which the ovum rests is termed the *decidua vera*. This covers the uterine walls ; it becomes very vascular, and its vessels communicate directly with the sinuses of the uterus. That portion of the decidua vera which develops into the placenta is called the *decidua serotina*. When the impregnated ovum reaches the uterine cavity the opening of its neck becomes closed by a plug of mucus. Gradually the decidua serotina and the villi of the chorion which are in contact with it develop and form the *placenta*, the organ by which the connection between the mother and the fœtus is maintained throughout the remainder of the uterine gestation. The circulation of the blood between the mother and the fœtus takes place through the umbilical vessels—viz., two arteries and one vein, the former conveying venous blood from the fœtus to the placenta, the latter arterial blood from the placenta to the fœtus. These vessels are derived from the allantoic vessels. The *umbilical cord*, consisting of the coils of the umbilical vessels surrounded by a gelatinous tissue, is therefore developed

from the allantois; it appears at about the end of the fifth week. The omphalo-mesenteric vessels and the umbilical duct have become obliterated by this time.

LECTURE LI.

THE DEVELOPMENT OF THE FŒTUS.

In speaking of the further development of the fœtus I will briefly describe the development of the principal parts —viz., of the spine, the ribs, sternum, limbs, cranium and face, the vasculatory system, the respiratory, digestive, and genito-urinary apparatus, and the nerve and muscle tissues. In giving the periods of the development of these various parts, I will follow the chronological table of *Beaune* and *Banchard*.

During the *first week* the impregnated ovum is in the Fallopian tube and undergoes but little change in size and form. During the *second week* the ovum passes into the uterine cavity; it becomes embedded there in the decidua and rapidly increases in size. The amnion, the allantois, the medullary groove, the notochord, the neural canal, and the separated masses of mesoblast at either side of the neural canal, are developed during the second week, so that at the end of the week there is a distinct indication of the developing embryo.

The *spinal column* now begins to form in the following manner: The mesoblastic masses on each side of the neural canal begin to segmentate laterally, until at each side we find a series of quadrilateral masses which in number correspond to the number of the permanent vertebræ. These segments extend forward and inward until they surround the notochord, which is situated in front of the neural canal, occupying the place of the bodies of the forming vertebræ. Gradually the segments extend backward and inward, surrounding the neural canal. The notochord and

the neural canal are thus enclosed by a mass of mesoblast which constitutes the membranous matrix of the vertebræ. At about the fifth or sixth week chondrification of these segments begins.

The permanent vertebræ are developed from the adjoining halves of two of the above-described protovertebral summits—the part which extends forward surrounding the notochord forms the bodies, the part enclosing the neural canals forms the arches, of the vertebræ. The canal formed by the arches of the so-formed vertebræ is lined with epiblast, from which the nerve structures of the spinal cord are developed; the spinal column is surrounded by hypoblast.

The *ribs* are formed by lateral extensions from the vertebræ; these extensions pass forward and inward, become detached from the vertebræ, and soon become cartilaginous, forming membrano-cartilaginous bars corresponding to the number of the ribs.

The *sternum* is formed by a fusion of the anterior ends of the upper nine ribs on each side.

The formation of the *cranium* begins at a very early period by a bulbous expansion of the cephalic end of the neural canal.

From the epiblastic lining of this part of the neural canal the brain is developed, while from the epiblastic layer covering this part of the neural canal the scalp is formed. The membranes of the brain, the bones of the cranium, the skin proper, the blood-vessels, and the muscles of the cranium are developed from a mesoblastic mass from the protovertebræ which extends upward between the two layers of the epiblast. The bulbous expansion of the cephalic end of the neural canal gradually divides by constriction into three compartments, which are known as the *primary cerebral vesicles*. The epiblastic lining of these develops into brain structures as follows: The lining of the upper vesicle forms the optic thalamus, the cerebral hemisphere, and the corpus striatum on each side; that of the middle vesicle forms the

corpora quadrigemina, and that of the posterior vesicle forms the medulla oblongata; the communicating interior of the three vesicles constitutes later on the general ventricular cavity.

The vesicles are at first straight, one upon another, but are gradually bent forward, forming a double curvature, the anterior or lower of which forms the frontal, the posterior or upper the occipital, protuberance. I have already stated that a mass of mesoblast from the protovertebræ extends upward between the two epiblastic layers, and that from this mesoblastic mass the bones, etc., of the cranium are developed. The bones of the base of the cranium are developed by a chondrification of this mass which takes place at about the fifth or sixth week. The bones of the roof of the cranium are developed later on between membranes. The notochord terminates in a tapering end at the cephalic end of the neural canal, and is embedded in the mesoblastic mass between the two epiblastic layers.

The *face* is developed in a similar manner as the spine and the cranium—viz., by laminæ or processes which become cartilaginous and develop into the bones of the face. These processes or visceral laminæ present clefts between them, so that at each side of the region of the neck and face we distinguish four such clefts and arches. The first of these is called the *mandibular arch;* it contains a cartilaginous mass, at the distal end of which is developed the lower jaw. From this arch a process extends forward, from which the superior maxillary and the malar bones are developed. The cleft between the first visceral arch and the above-named process forms the mouth. Sometimes the process from which the superior maxillary bone is developed does not fully unite in the middle line; the result is the condition which is familiar to all of you—viz., the *cleft palate.*

From the other visceral arches the hyoid and portion of the temporal bone and the ossicles of the ear are developed.

The various structures of the hard and soft parts of the face are the result of this differentiation during development.

The points and periods of ossification of the jaws and other bones of the face you will learn in your lectures on anatomy.

The development of the teeth I have already described in detail in a previous lecture. The germs of the teeth appear first during the *sixth week*. Ossification of the lower jaw also begins during that week. The ossification of the upper jaw begins during the *seventh week*. The hard palate begins to unite at about the *eighth week*.

The *limbs* appear about the fourth week as leaf-like appendages from the trunk. By about the *eighth week* the arms, forearms, thighs, legs, and digital clefts are distinctly visible.

The development of the *blood circulatory system* goes through three distinctly different stages before the regular system is complete. We have, *first*, the *vitelline* circulation, by which the embryo receives its nourishment from the yolk or vitellus; *second*, the *placental* or *fœtal* circulation, where the fœtus derives arterial blood from the mother through the placenta; and, *third*, where the individual receives its nutrition through its own organs, as is the case after birth.

The *vitelline* circulation consists of the circulation of a fluid between the area vasculosa of the yolk and the embryo.

The circulatory system at this period consists of a heart which is nearly tubular, and of two arteries and two veins.

The fluid circulating in this system is blood containing primitive red blood-corpuscles. The heart is developed by the formation of a cavity in a mass of cells from the visceral layer of the mesoblast. The mass of cells arranges itself in two layers around this excavation. The inner layer forms the pericardium, the outer the muscle sub-

stance of the heart. The excavation is at first separated longitudinally in the centre, so that in the earliest stages of development the heart consists of two tubes placed side by side. Each of these has an artery and a vein. Later on the two tubes coalesce, so that the heart consists of one tubule with two arteries and two veins.

The primitive blood-vessels at this stage are also developed from mesoblastic cells of the visceral layer.

The *red blood-corpuscles* at this period are formed from the nuclei of the mesoblastic cells. These nuclei collect a mass of protoplasm around themselves, so that at this early period they resemble white blood-corpuscles. Later on they assume a reddish tinge and the nucleus disappears.

The *white blood-corpuscles* in the embryo are first formed in the liver.

As the umbilical vesicle diminishes and the placenta develops, important changes take place in the circulatory system.

The heart, at first tubular, becomes elongated, twisted upon itself, and finally divides by transverse septa into three compartments. The posterior of these forms the auricles; the middle, the ventricles; the anterior, the aortic bulb, at which the large vessels at the root of the heart are developed.

The next change is the division of the auricular and ventricular cavity into the right and left auricles and ventricles.

The anatomy and characteristics of the fœtal heart and circulatory apparatus, as well as the placental or fœtal circulation, I have described in detail in a previous lecture. I will, therefore, say only a few words on the development of the blood vessels. In speaking of the vitelline circulation I said that it was maintained by a tubular heart, two arteries, and two veins. As the placental circulation develops, the two arteries, which from the tubular heart pass

downward along the primitive spinal column, unite, forming one vessel, the aorta; the portion of the two primitive arteries above the point of fusion forms the primitive aortic arches from which the vessels of the head, etc., arise.

The vessels at the lower part of the body are developed at the same time. From the lower end of the aorta two vessels spring, the hypogastric or umbilical arteries, by which blood is returned to the maternal placenta. Later on the external iliac and the femoral arteries are developed from a branch which arises from the umbilical arteries.

In speaking of the development of the *veins*, we must consider them under two headings—viz., *visceral* and *parietal* veins.

The *visceral* veins are derived from the vitelline veins—viz., the veins which return the blood during the vitelline circulation.

The two veins later on unite, forming the *sinus venosus*, which opens into the auricular part of the primitive heart.

The two vitelline veins enter the abdomen and pass toward the location of the future liver. This organ now begins to form around the vein; branches and capillary plexuses are formed from them, which finally form the hepatic veins, the portal vein, and those of the stomach and intestines. The *parietal* veins are developed from two short vessels, called the *cardinal* and *primitive jugular veins*, which return the blood from the embryo into the auricular portion of the tubular heart; these, by union, gradually form the vena cava, the iliac veins, etc.

The veins from the lower part of the body are developed from the cardinal, those of the head and upper part of the body from the primitive jugular veins.

The periods of the development of these various parts are as follows:

The first indication of the development of the heart is noticeable at the end of the second week.

During the fourth week the separation of the heart into a right and left half is complete. The activity of the umbilical vesicle ceases at the end of the fifth week, when the placental circulation is established.

The development of the *alimentary canal* begins at a very early period by an inflexion of hypoblast ; this forms a tube which extends from one end of the embryo to the other, being closed at the caudal and cephalic extremities ; this tube freely communicates with the umbilical vesicle. Gradually the tube divides into three compartments, named respectively the *hind-gut*, *mid-gut*, and *fore-gut*. From these, then, the various parts of the alimentary canal are developed, as follows : from the fore-gut, the pharynx, œsophagus, stomach, and duodenum ; from the hind-gut, the rectum; and from the mid-gut, the remaining portions.

The *mouth* and *buccal cavity* are formed by involutions of the outer layers of the blastodermic membrane near the upper end of the fore-gut.

The *anus* is similarly formed by an involution at the lower end of the hind-gut.

The *liver* is developed at about the end of the third week.

The *gall-bladder* and the *pancreas* are developed about the second month ; also the *salivary glands*.

The *respiratory* organs begin to develop at about the fourth week as a dilatation or diverticulum from the middle of the upper part of the fore-gut. Gradually a pouch is developed at either side of this diverticulum ; these communicate with it, and through it with the upper part of the fore-gut. In the further development secondary pouches are formed which communicate with those first formed, and thus by the eighth week these pouches have developed into lobulated lungs.

The portion where the median diverticulum communicates with the upper part of the fore-gut develops into the *trachea* by the formation of cartilaginous rings ; these form during the seventh week. About the fourth month

the *larynx*, with the cartilages and *vocal cords*, is formed. At about this time a delicate membrane develops which separates the pleuro-peritoneal cavity into two—viz., the thoracic and abdominal.

The *skin* is developed from the external and middle blastodermic membrane, the epidermis from the external, the true skin from the middle layer. A distinction of the two layers of the skin is first noticeable at about the fifth week.

The subcutaneous and adipose tissues are only developed at the fourth month.

The nails and hair appear between the third and fifth months, the papillæ about the sixth, and the glands of the skin about the same period.

The development of the eye is first noticeable by the appearance of the primitive ocular vesicle, which is formed during the third week. The nervous and non-vascular structures of the eye are developed from epiblasts; the vascular structures, from the mesoblast. The process of the development of the eye is too complicated to be described in detail in the short time I can spend on the subject of embryology.

The *eyelids* are formed at the end of the third month; they are united at first, but separate before birth.

The development of the ear is indicated by the appearance of the primitive aural vesicle at the end of the third week, shortly after the appearance of the primitive ocular vesicle.

Your special lecturer on the eye and ear will dwell in a more detailed manner on the further development of these organs.

There remains yet for me to say a few words on the development of the urinary and the generative organs and the nerve structures.

The development of the *urinary* organs is rather complicated; they are of mesoblastic origin.

The *kidneys* are developed from the lower part of the set of tubular glands which are known as *Wolffian bodies.* These glands consist of three sets of tubular organs; each of these opens with one end into the body cavity of the embryo, with the other end into the hind-gut. They are situated in front of the primitive vertebral column, and each has an excretory duct.

The *Wolffian bodies* are developed by the end of the third week; they increase until the sixth week, then gradually decrease, and disappear about the third month.

The kidneys are developed from the posterior or lower set of these tubular glands, or *segmental organs,* as they are called; their excretory ducts are the ureters.

The *urinary bladder* is formed about the third month by a dilatation of the lower part of the allantois.

The *generative organs* are the same in the two sexes in the first stages of development. The first indication is the appearance of the genital ridge, which is a thickening of the peritoneal cavity near the Wolffian body. From this ridge are developed the testicles in the male and the ovaries in the female. A distinction of the sexes is perceptible at about the seventh week.

The *external genital organs*, like the internal organs, pass through a stage in their development in which no distinction of the sexes is possible.

The first step is that the *cloacal* opening is separated by a septum which constitutes the future perineum; this is formed about the second month. The posterior part of the so-divided cloacal opening constitutes the rectum; the anterior part, the urogenital sinus. About the sixth week a small elevation, called the *genital tubule,* is formed in the front part of the cloaca. Gradually this tubercle is enclosed by two folds, the genital folds. Toward the second month there is a longitudinal furrowing of the genital tubercle which forms the genital furrow.

After the second month the differentiation of these

organs takes place. In the female sex the urogenital sinus forms the *vagina*, the genital tubercle, the *clitoris*, and the genital folds the labia of the *vulva*.

In the male sex the genital tubercle develops into the *penis*, the genital furrow into the *urethra*, and the urogenital sinus forms the posterior parts of the urethra. These parts develop during the third and fourth months.

The *nerves*, like the other nerve structures—viz., the brain and spinal cord—are developed from epiblast. The primary divisions of the brain, as described before, are visible during the third week.

The special ganglia and the roots of the spinal nerves are perceptible at the end of the fourth week. The posterior roots of the spinal nerves, the sheaths of the nerves, and membranes of the nerve centres, are formed during the sixth week.

The nerve structures of the eye, ear, olfactory apparatus are developed during the first five weeks. The finer divisions of the great nerve-centres develop during the third month. The first indication of the development of the sympathetic nervous system is visible at the end of the eighth week; the sympathetic nerves are developed from the ganglia of the spinal nerves.

This completes the intrauterine development of the fœtus, as briefly as possible, but the new-born infant is by no means successfully developed. In my last lectures I have pointed out some of the further changes which the individual undergoes during childhood and youth and puberty.

The development of the body is complete only when adult life is reached.

Of particular interest to you is the development of the teeth and jaws, with the phases of which you are all familiar.

I now close my series of lectures with the hope that this little work may be a guide in your studies and enable you to follow the subject with a better understanding.

QUESTIONS AND EXERCISES.

SUBJECT.—*Reproduction, Growth, and Development. Lectures XLIX.-LI. inclusive.*

753. Describe the human ovum.

754. Explain the phenomena of menstruation.

755. What is a Graafian follicle ?

756. Describe a spermatozoon.

757. Where and how is the impregnation of the ovum in the human female effected ?

758. What is a corpus luteum ?

759. What is the first change in the ovule after its impregnation ?

760. Name the layers of the blastodermic membrane, and state which structures are developed from each.

761. At what period are the germs of the teeth first visible ?

762. What is the placenta ?

763. Name the fœtal membranes.

764. Describe in brief the development of the principal parts, such as the spinal cord, the cranium, the face, the respiratory and digestive apparatus, and the circulatory system.

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